# *Efficiency evaluation and improvement guidelines for community colleges of Connecticut:: a data envelopment analysis (DEA) approach*


Mills, Joseph J.

+ 2


# Abstract

Title: Efficiency Evaluation and Improvement Guidelines for Community Colleges of Connecticut: A Data Envelopment Analysis (DEA) Approach.

Joseph Mills, BSc., MSc.

Dissertation submitted for the degree of Doctor of Education (EDD) to the

School of Education at University of Durham

Study directed by: Dr. Robert Coe and Prof. Peter Tymms

Tertiary education at Connecticut's Community Colleges, in the United States, is facing a public outcry for a higher level of accountability for the resources appropriated to higher education. This study utilized Data Envelopment Analysis (DEA) to determine the technical efficiency of and provide Improvement guidelines to these twelve Community Colleges.

Three research questions were used to direct this study:

Question #1: How do institutions of the Community College System of Connecticut compare to each other regarding their levels of Efficiency?

Question #2: What conditions may account for the differences in the level of success within similarly efficient colleges?

Question #3: What factors or constraints create the varying score among the inefficient colleges?

Data for eleven variables, seven inputs and four output, were collected on each of the twelve Community Colleges, but due to the high level of correlation that existed between the variables only three inputs and four outputs were used to characterize each college in the model.

The analysis indicated that seven colleges were being run efficiently and five had less than 100% efficiency. However, the small numbers of colleges in the study handicapped the DEA procedure, since the number of colleges could not be changed the number of variables was decreased. This resulted in a decrease in the efficient units.

The study concluded that DEA was, in principle, well suited for the performance assessment of the colleges. However, the validity of the model is compromised if only a small number of colleges can be entered into the analysis; either a very small number of variables can be considered ( which violates one's conception of the ways colleges are to

be judged, and the numberof independent variables that can be considered), or the requirements of the model are violated ( which necessarily produces the result that a large number of colleges are spuriously designated as 100 % efficient)

May 2004

# TITLE

# Efficiency Evaluation and Improvement Guidelines for Community Colleges of Connecticut: A Data Envelopment Analysis (DEA) Approach

JOSEPH J MILLS

(EdD)

2004

DURHAM

# Table of Contents


a. Abstract
b. Title
c List of Figures

Chapter 1: **Introduction**

Scope of the study

**Background**

1.1 Concept of the Community Colleges in the United States
1.2 Introduction to the Community College System of Connecticut
1.3 Purpose of the study
1.4 Significance of the study
1.5 Delimitation of the study

Chapter 2: **Review of Related Research**

2.1 Research Questions
2.2 Measures of Efficiency:
Ratio
Regression Analysis
Data Envelopment Analysis
2.3 Review of past DEA studies

Chapter 3: **Design of the Study**

3.1 Methodology of DEA
3.2 Mathematical Formulation of the DEA
3.3 College Accreditation….. leveling the playing field
3.4 Input – Output Studies
3.5 Outputs to the study
3.6 Inputs to the study
3.7 Non-categorical Variables
3.8 Relationship of study results to study questions

Chapter 4: **Analysis of Data**

4.1 Description of DEA (Frontier Analysis) Model
4.2 Analysis of Model Data
4.3 Analysis of Model Results
4.4 Efficient Reference Set
4.5 Analysis of individual Efficient and Inefficient colleges
4.6 Improving the efficiency rating of Inefficient colleges
4.7 Sensitivity - Validation Analysis of the Model Results

Chapter 5: **Summary and Conclusion**,

5.1 Summary
5.2 Conclusion
5.3 Policy recommendation and implications
5.4 Closing remarks

**Glossary:** Meaning of terms

**Reference**

# APPENDICES

A. How Data Envelopment Analysis (DEA) works

B. Input/output data sheet for the Community College System of Connecticut

C. Degrees and Certificates awarded in 1999-2000 year in the Community College system of Connecticut.

D. DEA model input data sheet.

E. 100 top Associate Degree producers, 1999-2000.

F. BCC Model Run.

# List of Tables


3.1 Output Variables used to characterize the Community Colleges of the System

3.2 Input Variables used to characterize the Community Colleges of the System.

4.1 XY Correlations between Input Variables

4.1.1 Comparison of Efficiency Sores with different number of variables

4.2 Efficient Colleges

4.3 Comparison of the Efficient Colleges

4.11 Comparison of in efficient units

4.12 Summary of Sensitivity Analysis

4.13 Efficiency Scores Sensitivity (ESS) Analysis

4.14 ESS as per model variables

4.15 ESS as per variables values

4.16 Summary of DEA Model Results

# List of Figures

2.2 Pareto-Koopmans Plot

4.1 Production Frontier Line for CCR Model.

4.2 Production frontier Lines for BCC Model

4.15 Workforce Analysis

# Chapter 1
# INTRODUCTION

## Scope of the study

One of the most significant problem areas for executive decision at institutions of higher learning deals with the allocation of available resources. Resources such as space and staff as well as budgeted funds all bear on the issue of achieving institutional goals. Methods that were used to evaluate what was currently being achieved as well as how resources might best be arranged, along with the attendant consequences, were needed for this purpose. Such methods as were available from budgetary analyses and cost accounting practices did not deal adequately with many aspects of the problem. These aspects were the best utilization of fixed resources and the ability to deal with many outputs and inputs variables of the education function, that interact in a variety of unknown and unpredictable ways (Bessent, 1983).

The aim of this study was to perform an efficiency evaluation and provide improvement guidelines for the twelve community colleges of Connecticut using a Mathematical Linear Programming derived tool called Data Envelopment Analysis (DEA) in a computer model. The DEA model has the ability to handle multiple inputs and outputs of the operation of any given organization (without a prior knowledge of the production function between the inputs and outputs), particularly the not-for-profit institutions such as colleges and universities. And so, DEA is considered a superior tool to the Ratio and Multiple Regression Analysis methods previously used to determine a measure of efficiency of these institutions (.Sexton, 1986)

The study aimed to answer the following research questions:

A) How do institutions of the Community College System of Connecticut compare to each other regarding their levels of Efficiency? In other words, based on the variables (inputs and outputs) selected to characterize the community colleges, what is the mathematically determined efficiency of each college.

B) What conditions may account for the differences in the level of success within similarly efficient colleges? The differences amongst the efficient units were determined by comparison of the weighting of the input and output variables of these efficient units.

C) What factors or constraints created the varying scores among inefficient colleges? This question was answered directly from the results of the model. All the inefficient units were supplied with the specific shortcomings of the input/output variables as guidelines to increase the level of efficiency of each unit.

To determine the efficiency and the best practice guidelines of the operations of the Community Colleges ( Decision Making Units, DMU's as they are called in the study) using DEA, the study develops a working knowledge of the nuances of the operation of the System of Connecticut Community Colleges and DEA. Initially, the study developed the theory and mission of the Junior Colleges (the first name given to the

Community College) in the United States, which was followed by a historical development of the Community Colleges System of Connecticut.

The previous methods utilized to determine the efficiency of colleges, namely the Ratio Method and the Multiple Regression Analysis Methods were discussed. Similarly, the study showed the origin and mathematical development of DEA. In the Design of the Study, the bulk of the knowledge acquired on the Community Colleges and the DEA method were intertwined to determine the best way to use DEA to make an efficiency assessment on these institutions.

The model had a wide variety of input and output variables, for which data was collected, to make the efficiency determination. However, because of the obviously high level of correlation that existed between the variables of the operation of a community college, only seven variables were extracted from the following list of:

a) Total number of student contact hours.

b) Total instructional area footage

c) Full Time Equivalent Instructors.

d) Total direct instructional expenditure

e) Physical Plant expenditures (Grounds, Building Maintenance and Custodial Services)

f) Overhead expenditure for Administration and Academic Services

g) Student services Expenditure

h) Revenue ( Tuition, Fees, Government Funding and Credit Free Programs)

i) Total number of Graduates

j) Employer and Admission Office Satisfaction Factor

k) Total credit awarding grades (A…D..P)

l) Percentage of credit awarding grades given.

Apart from the drawback of the correlating variables, the model had a second handicap concerning the number of inputs and outputs used to analyze a given number of units. The Linear Programming make up of the Model would not allow the product of the number of inputs and outputs to be greater than the number of units (Colleges) in the model since the Connecticut Community College System comprises of twelve colleges, the maximum allowable total number of inputs and outputs was seven (Three input and four outputs) .

**Background**

## 1.1 Concept of the Community College in the United States

Throughout much of the nineteenth century, the belief that the United States was a nation blessed with unique opportunities for individual advancement was widespread among Americans and Europeans alike, as evidenced by the massive influx of Western Europeans; Italians, Irish and Portuguese into the United States for this period. The cornerstone of this belief was the relatively wide distribution of property (generally limited, to be sure, to adult white males) and apparently abundant opportunities in commerce and agriculture to accumulate more. But with the rise of the mammoth corporations and the conquest of the frontier in the decades after the Civil War, the fate of the "self made man " – that heroic figure who, though of modest origins, and had triumphed in the competitive marketplace through sheer skill and determination –

eventually was challenged by new technology and knowledge system. In particular, the fundamental changes then occurring in American economy – the growth of huge industrial enterprises, the concentration of propertyless workers in the nation's cities, and the emergence of monopolies – made the image of the hardworking stock boy who rose to the top seem more and more like a relic of a vanished era (Brint and Karabel, 1989).

Hence, to adhere to the American dream of individual advancement, which then existed under dramatically, changed economic and social conditions of the nineteenth century, new routes to success had to be formulated. Andrew Carnegie ( Wyllie, 1954 ), a steel magnate and a very rich and influential person of that era, was convinced that with the appearance of the giant corporations, it became more and more difficult for a young man to rise from rags to riches. He( Carnegie) never bought into the concept of the redistribution of wealth for the reconciliation of the rich and the poor. In concert with other philanthropist of the times, Carnegie advanced the idea to the businessmen and the population at large, that ordinary Common School training would provide the skills necessary for economic development. As quoted by Wyllie (1954) in the Self-Made Man in America, as much as 84 % of the prominent businessmen in 1900 had not been educated beyond a high school level. Thus, getting ahead in America in the 1900s depended highly on the skills in the marketplace than that in the classroom.

Higher Education during the early nineteenth century was in a very dismal state, the loose array of students who attended high schools, colleges, universities and professional schools beyond elementary schools did not comprise a system. There was no sequential order of attending higher education as exists today. And so, many times the professional schools competed with high schools for students and vice versa. Moreover, the Common School education, which supposed to have been equipping the citizenry with tools for economic success, was educating the students for life in a democratic society ( Brent and Karabel, 1989). Hence, the business sector became very disdainful of the diplomas awarded from these institutions (Common Schools), they thought that this training was harmful to young men and unfit for the rigors of the practical world of commerce and industry. Still by 1920, despite the chaotic and relatively undifferentiated state of the American education, outlines of a very orderly and stratified education system were becoming very visible. The development of a hierarchically differentiated education system appealing to the needs of the labor market provided a pathway to success in the competitive market. This formation of the means of upward mobility through education gave new life to the American ideology of equality of opportunity at the very moment when fundamental changes in the economy threatened to destroy it. As quoted by Brint and Karabel (1989), America's large and open educational system now provided an alternative means of getting ahead. Vast in equalities of wealth, status and power, though there might be, the ladders of opportunity created by new education system, helped the United States retain its national identity as a land of unparalleled opportunities for individual advancement. The concept of upward mobility through education, and more so, higher education was thereinafter taken for granted. However, when compared to Japan, Canada and even Sweden, statistics show that the United States sends more young people to college and universities than these countries.

Fundamental to this system of American Higher Education was the two-year junior college or the community college as it came to be called. This institution began at the time the American Education system was being transformed to provide the upward mobility, as mentioned in the previous section. In a nutshell, one can abbreviate the mission of the two-year colleges by saying that these institutions provided the egalitarian promise (equal access, etc.) of the world's first modern democracy and the constraints of its dynamic capitalist economy. From an enrollment of ten thousand in 1920, the community colleges have provided an education for as many as five million students in 1990 and because of their overwhelming success, the two-year colleges have spread beyond the United States and have been opened for business in Japan, Canada, Yugoslavia and the Caribbean.

Over the period of their existence, the Community Colleges had attempted many tasks for which they were not very equipped, but did a praiseworthy job, anyway. Among these many functions were a) to extend opportunity and to serve as agent to educational and social selection, b) to promote social equality and to increase economic efficiency, c) to provide the students with a common cultural heritage and to sort them into specialized curriculum, d) to respond to the demands of subordinate groups for equal education, e) to answer pressures of employers and State planners for differentiated education, f) to provide a general education for citizens in a democratic society and technical training for workers in an advanced industrial economy. Said in short term, the fundamental mission of the Community Colleges had been to democratize the playfield of American Higher education, by providing to those formerly excluded an opportunity to attend college.

The Junior Colleges as the Community Colleges were initially called, gained their high level of popularity and credibility due to their direct link or transferability of the academic work, they forged with the four-year institutions. As quoted by Brint and Karabel (1989), students who attended the two-year institutions did so on the basis of their claim to be " real" college students. The only way this was validated was by the completion of the Liberal Arts courses that would in fact receive academic credits at the four-year colleges and universities. However, many researchers of the role of the Junior Colleges in the scheme of Higher Education postulated that the administrators of the four-year colleges, who gave the Junior Colleges their footing in the beginning, had a totally different motive to the development of the two-year institutions. Their aim was to divert the masses of under prepared students, reaching out for a higher education, from their doorstep.

Another contradictory pressure the Junior College faced was a more natural one; all the graduates from the four-year institutions were being prepared to perform the tasks of managers and administrators of Industry and Commerce. There was an insufficient quantity of the managerial jobs available for the potential number of graduates, and so, the graduates of the two-year colleges were forced to compete with the graduates of the four-year colleges for the non-managerial jobs that were initially intended for the junior college graduates. This situation was a quite natural result of the democratization of the American Higher Education – the education and occupation aspiration of the students outran the objective possibilities by a substantial margin (Russel, 1908). The United States being the class –stratified society that it was had something threatening the status quo by developing an educational system, which aroused high hopes, but merely destroyed them at a later date.

The idea of a "REAL" education as defined by the four-year colleges, and something that the two-year institutions wanted to embrace, to maintain their status and transferability to the four-year colleges, had to be abandoned for a differentiated education. This new model was able to fit students to their different vocation futures. Researchers of higher education clearly stated that if mass education were to realize the promise of democracy, separate vocational tracks had to be created. The logic behind the vocationalization of the Junior College System was quite sound – if a society generated more ambition for upward mobility than the actual opportunity available, vocationalizing both at the secondary and higher education level was very necessary. As a result of this vocationalization, the student population at the Junior Colleges dropped because of the change in the students' perception of the quality and transferability to the four-year colleges and universities. However, toward the latter half of the 20 th century ( 1960-1999), this viewpoint of a decreased quality of higher education because of vocationalization, had changed. And so today, more than 42% of the students attending an institution of higher education in America, started at the Community Colleges

## 1.2 Introduction to the Community College System of Connecticut

The Community College System of Connecticut comprises twelve two-year public institution of higher education that share a common mission to make educational excellence and the opportunity for life long learning affordable and accessible to all citizens of the State of Connecticut. As a secondary mission, the colleges of the System seek to enrich the intellectual, cultural and social environment of the communities they serve. The colleges also support the economic growth of the state with programs that provide business and industry with skilled well-trained workforce. As outlined by Cox's (2001), the colleges' primary responsibilities are to provide:

(I) Occupational, vocational, technical, and career education designed as training for immediate employment, job training, or upgrading of skills to meet individual, community, and state workforce needs;

(II) Programs of general study, including remediation, general and adult education;

( III) Programs of study for college transfer, representing the first two years of the baccalaureate education;

(IV) Community service programs, including educational, cultural, recreational, and community-directed programs; and

(V) Student support services such as admissions, counseling, testing, placement, individualized instruction, and instruction for students with special needs.

In 1946 the Connecticut Engineering Institute was opened to develop competent technicians to meet the needs of the manufacturing industry. Later in 1955, the first technical college, Hartford State Technical College was given the charter to grant two-year degrees. Within ten years, four more technical colleges were opened; Norwalk, Norwich, New Haven and Waterbury. Soon after, the five institutes were incorporated into a system of two years higher education, with a separate board of trustees, and named the State Technical Colleges.

In unison with the development of the State Technical Colleges, the General Assembly of the State of Connecticut established a system of two- year community colleges in response to the recommendations by a special study commission that advocated making higher education available to all citizens of Connecticut. In 1965, two community colleges (Manchester and Norwalk) were opened for business and within seven years, ten more colleges were operational. After an in-depth examination of the two systems, the state legislation consolidated these two separate systems of twelve community colleges and five technical colleges under the administration of a single board of trustees and renamed the system the Community- Technical College System. In 1992 the merger was completed that resulted in twelve Community- Technical Colleges, five community colleges combined with five technical colleges respectively and the remaining seven were given the permission to develop programs of study that were previously offered at the technical colleges. Since then, the colleges have learnt to serve a new and diverse student population to meet the common commitment to access and opportunity through affordable and accessible higher education.

Following the national model for two-year comprehensive colleges, the board of trustees that oversees the administration of the twelve Community- Technical Colleges changed in 1999 the name of each college to Community College. The Community Colleges award associate degrees and certificates in over one hundred career areas. Each degree program requires a core curriculum and the general education courses, making the Community College Education the combination of career training and liberal arts that is essential in today's complex and changing society. Moreover, the General Studies programs allow students the flexibility to work for a college degree and personal enrichment, to achieve individual education goals, or to meet transfer requirements for specialized majors at four–year institutions of higher learning.

## 1.3 Purpose of the study

The problem of limited resources has always plagued Institutions of Higher Education and even to a larger extent the Primary and Secondary Education Systems of Connecticut. However, as we begin the 21st century, we have found ourselves facing many controversial issues that could lead to the removal or dismantling of many needed programs on the college campuses, today. The State Legislature faced with diminishing revenue base, and with the responsibility for funding the community colleges in Connecticut is requiring that funding should be tied to some operational efficiency indices.

The Community College System of Connecticut has recently received a list of the measures of efficiency from the State Commission on Higher Education. The intention of this governing body was to ensure that these measures be met by the various member institutions of this System. To address these measures, there is a need to develop a comprehensive method to determine the level of efficiency at which these colleges are performing, compared to each other or to colleges within a similar system of Higher Learning. Banathy (1991) and Athanassopoulos and Shale (1997), both researchers in the United States and the United Kingdom, were convinced that the performance accountability of the Community Colleges was very difficult to measure, because of the variety of methods postulated to deal with the variations in the goals in the determination of efficiency at the Community Colleges.

In previous similar determinations, the Regression Analysis Method has been used extensively in determining which parameters would affect certain required outcomes in an efficiently or inefficiently operated institution. This method of determination of efficiency is a far cry from the true efficiency determination as utilized by the Engineering and Economics discipline. Engineers and Economists make a comparison between the Inputs and Outputs of any process in determining its efficiency. Hence, it is necessary for Education Researchers at the Community College System of Connecticut to develop a list of Inputs and Outputs that would characterize the Mission of the Community Colleges and use these lists to calculate efficiency markers (as engineers and economists do) for the individual colleges within the System. The purpose of this study was to determine the efficiency of the individual community colleges, as compared to each other, and to use the results of the analysis to provide guidelines for the educational improvement of the colleges.

## 1.4 Significance of the Study

This research addressed the issues of efficiency, and the results of the study that provided distinct policy prescription to improve the overall learning environment at the Community Colleges of Connecticut. Potentially, the most valuable outcome was the identification of sources of efficiency and the estimation of the amounts of inefficiencies. The augmentation of outputs as well as the conservation of resources was obviously of interest in the matters of public management and policy. Hence, there was interest in the methods used for evaluating the efficiency of the units of the Community College System.

In the search of a reliable method for calculating the efficiency of the community colleges, a recently developed (less than fifty years) method called Data Envelopment Analysis (DEA) Method was designed specifically to examine the efficiency of not-for-profit institutions such as colleges and universities in a multiple input- multiple output setting. This algorithm is a direct outcrop from the procedures of Mathematical Linear Programming as used in Operations Research and System Analysis, and so, it can be considered a procedure well grounded in the rigors of mathematics.

The significance of the study can be outlined in the following ways:

a) The study identified a peer set of efficient colleges (with similar outputs and resources level), which served as examples for the resource allocation decisions and the achievement target of the less efficient colleges.

b) The study supplied the data on the utilization of the college resources, which assisted the decision makers in the reallocation of resources.

c) The study developed managerial information on the output augmentation level and the resource conservation levels that could make an inefficient unit into an efficient one.

d) The study pinpointed the specific inputs, which were causing the college to have an inefficient rating, and so, the strategic planners of the college should focus on these inputs for educational improvements.

In reflective thought, I hoped the study made some contribution to the understanding of the operation of a community college, as it played a vital role in the realization of the educational goals of ordinary people.

## 1.5 Delimitation of the study

1. This study was done to analyze the level of performance of the Community Colleges of Connecticut as compared to each other, and at no instance should the results of this study be used to characterize the behavior of the community colleges throughout the United States or the United Kingdom. The main limitations were as follows:

1. The operational variables of the study, the inputs and the outputs were best selected on the basis of availability of data on the twelve Community Colleges of the System for the academic year 1999 - 2000. Although there are variables that can be selected that would further describe the performance of these institutions, data has not been collected to support their inclusion into the study.
2. These Community Colleges may have a common mission as mandated by the Central Office, however, a level of autonomy is still left to the individual colleges, and so, the tasks of the mission are approached differently, with stress placed on programs for the specific community (Service Area) in which a college is placed. Hence, a proposal to correct inefficiencies obtained from the overall study may or may not work at a specific institution. Applications should be done with caution.
3. Apart from the shortcomings of the entire study, there are inherent defects in the DEA procedure. The DEA model requires the analyst to specify and measure all the inputs and outputs for the study. If any valid inputs or outputs are omitted the results of the study can be biased against efficient consumers of input resources or efficient

producers the outputs. The incorrect input or output causes some DMUs to be given higher efficiency standing than they really are.

4. DEA procedure takes for granted that each unit of an input or output is identical to all other units of the same type. That is, within any input or output vector the units of measure should be the same. I believe that this is a potential discrepancy of the database and not of the DEA procedure and could appear in all methods of efficiency measure.
5. DEA assumes that for proportional changes in the input levels, there are correspondingly proportional changes in the output levels. This is referred to as the 'Constant Return to Scale.' This allows all DMUs to be compared and scaled to a unit isoquant and so all the DMUs are evaluated on the same envelopment surface. Similarly, if the Ratio or the Regression method selects a linear surface they will face the same Constant return to Scale drawback. However, the software used in this study that was developed by Banxia Software Ltd of Glasgow, UK can select a varying return to scale, which is most appropriate for the evaluation of educational system.
6. The weights selected by the model for the input and output variables cannot be interpreted as values in the economic sense, like costs and prices, although they share the same mathematical representation as the maximizing factors for a Linear Programming Model.
7. Because the DEA procedure has its roots in Mathematical Linear Programming (MLP), DEA shares a very prevalent shortcoming with MLP. The product of the number of input variables and the number of output variables should not exceed

the number of Units being analyzed. This stems from the matrix method used to calculate the efficiency of the DMUs.

8. Because the DEA Model yields a relative efficiency score based on the best producer of the group of DMUs, all the efficiency scores developed cannot be considered independent of each other, and so, it would be invalid to use these scores as input variables to a Regression Analysis when the confidence interval of the scores are determined. Hence, it is necessary to use a " Bootstrap Method" to avoid this drawback of data dependence.

# Chapter 2

# Review of Related Research

## 2.1 Research Questions

The following questions served as the core around which this entire study was developed and provided a nucleus for the generation of the literature review for this efficiency assessment analysis of community colleges.

**Question #1: How do institutions of the Community College System of Connecticut compare to each other regarding their levels of Efficiency?**

**Question #2: What conditions may account for the differences in the level of success within similarly efficient colleges?**

**Question #3: What factors or constraints create the varying score among the inefficient colleges**

## 2.2 Measures of Efficiency

To measure the true strength of the DEA method, a comparison between the DEA and the existing procedures used for the determination of the relative efficiency of various organizations should be made. There were two procedures that warrant mentioning as this comparison was made, namely, the Ratio Analysis and Multiple Regression Analysis, and so, I chose to describe these two before I undergo a thorough in-depth analysis of the dynamics of the DEA procedure.

**Ratio Analysis:** This method promotes the determination of the efficiency of a system using the ratio of a single output to a single input. For example, the ratio of the cost of instruction (both full time and part time faculty) in a given department to the number of students graduating from that department is a measure of how efficiently the department converts instructional dollars into graduates. However, this method is woefully lacking in details of the true efficiency of this department of the college. There are many other variables to be considered within the operation of the department, before a correct determination of the efficiency of the conversion of all the inputs to the outputs of the department under consideration, is made. If this Ratio Method Efficiency, as determined above, is used to compare other departments within the college, very misleading results can emerge from this analysis. The ratio treats all the departments as if they were all the same. There is a definite need to include all the contributing variables, inputs and outputs to develop a true efficiency figure, and this cannot be done with this type of ratio analysis. To account for the multi-inputs and multi-outputs nature of departments within institutions of education, various ratios of efficiency would be calculated simultaneously using different pairs of input and output. Collectively these ratios tend to present a slough of numbers that give no clear indication of true efficiency (Sexton, 1981).

**Multiple Regression**. This method produces a single output level of performance of an organization based on contributing inputs. This method develops a relationship or function that can be used to calculate the predicted output level of a DMU, given its levels of input. The efficient DMU's lie above this relationship, which means they produce more output than the model allows with the inputs provided. In opposition, those that lie below the relationship produce less output with their inputs and are considered inefficient. Hence, relative efficiency is reflected in the residuals, where positive residuals indicate relative efficiency and the negative residuals show an inefficient operation. Further comments can be made about this method.

a) The parametric approach ( as is Multiple Regression Analysis) to efficiency determination typically uses the stochastic frontier method developed by Aiger(1977). This entails the estimation of a stochastic production frontier, where the output of a unit is a function of a set of inputs, the inefficiency and random error. The drawback of this technique is that it demands an explicit functional form and distribution assumption on the data as opposed to DEA which does not impose an assumption about functional form and so, less prone to mis-specification. In addition DEA is a non-parametric method that does not account for random error. However, since DEA cannot account for such statistical nise , the efficiency estimates may be biased if the production process is highly dominated by stochastic elements.

b) Multiple Regression Analysis determines efficiency relative to average performance as opposed to the best performance. Hence, it provides a negligible amount of direct information concerning the magnitudes of efficiency improvements that were possible at various DMUs in any given group.

The next section showed a description of the Data Envelopment Analysis method selected to determine the relative efficiency of the member colleges of Connecticut Community College System.

**Data Envelopment Analysis** (DEA)

In order to avoid any reiteration of the description of the DEA, the reader is directed to Section 3.1 of this study, where a more detailed and in depth description of the dynamics of the DEA and selection of the weights are considered.

## 2.3 Review of Past DEA studies

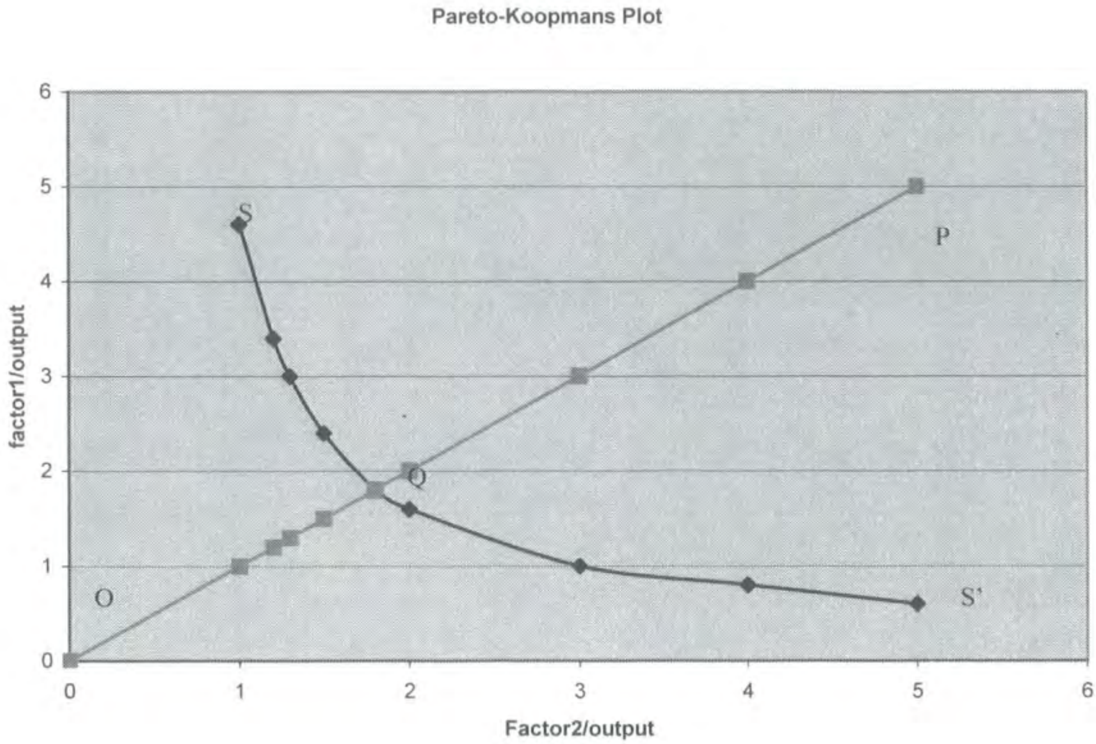
The basic nature of this research is one of an application of an existing theory and model to determine the efficiency and reasons for differences in performance of the twelve Community Colleges within the system of Higher Education of the State of Connecticut. As a result, I do not think that there was the need to analyze and critique the latest development in Data Envelopment Analysis (DEA) theory as is required in research work that deals with the mechanism or theoretical rationale of DEA. However, in the application of DEA, there have been improvements and extensions that have been made to the original methodology of the technique that need to be embraced or analyzed. Hence, I have selected to review only the previous analyses that have lent significant insight to the applications of DEA to Decision Making Units (DMU's), like Institutions of Higher Learning, in Higher Education .

The origin of Data Envelopment Analysis (DEA) stems from the two qualitative analysis works done by Pareto and Koopmans (1927,1951). The Pareto-Koopmans efficiency referred to Wilfredo Pareto and Tjalling Koopmans. Pareto was concerned with welfare economics, where he formulated the Pareto condition of welfare maximization by noting that such a function could only be a maximum if it was possible to increase one of its components without worsening other components of such a function. He postulated that as a criterion, any proposed social policy should be adopted if it made some individuals better off without decreasing the welfare of other individuals. Tjalling Koopmans, on the other hand, applied these above- mentioned concepts to production, which he referred to as Activity Analysis. He considered whether it was possible to increase an output without aggravating some other output under constraints allowed by factors of labor, capital and raw material (inputs).

These two researchers did not have any empirical data collected to confirm their early philosophy until the appearance an article written by M. J. Farrell (1956). This article demonstrated how the postulates of Pareto and Koopmans could be applied to data to make determinations on relative efficiency on systems from which this data came. Farrell considered in his simplest case a company using two factors to produce one product. On a coordinate system of axes ( Figure 2.2), the Y –axis represented the first factor per unit output and the X –axis represented the second factor per unit output. He placed a point P in the first quadrant of this coordinate system to represent the production of the company in question, and so, a line, OP, from the origin, O to P represented the various combinations of production of the company. He also inserted on the above-defined coordinate system, a line segment, SS', that was asymptotic to both X and Y axes in the first quadrant, this line segment represented various combinations of the two factors that a perfectly efficient firm might use to produce the unit output. The line OP crossed SS' at Q, hence, the point Q was said to represent an efficient firm using the two factors in the same ratio as P. It could be seen the Q produced the same output as P only using a fraction OQ/OP as much of each factor. Farrell defined the ratio OQ/OP as the technical efficiency of the firm P. This is demonstrated, quite clearly, in the graph that follows. It is evident that if the line segment SS' represents the production line of a perfectly efficient firm, then it leads to reason that the point Q on SS' represents an efficient unit and if Q is also on line OP, it represents an efficient production of firm P.

Then the ratio of the line segments OQ/OP is a comparison of perfection to actual which is defined as efficiency.

**Figure 2.2 Pareto-Koopmans Plot**



This article was considered the cornerstone or the best precursor for the studies that led to the development of the DEA method. As the number of variables (input/output) increased, to achieve some quantitative results on the methods of Activity Analysis, Farrell had to wrestle with a series of massive matrix inversions, which was very time consuming, to say the least.

At approximately the same time in 1957, when Hoffman (1957) pointed out to Farrell the ease with which the Activity Analysis computations can be done using Linear Programming, Charnes and. Cooper (1978) article cemented the relationship between the Activity Analysis and Linear Programming, and henceforth, most managerial efficiency calculations were done using Mathematical Linear Programming.

Two articles written by Charnes, Cooper and Rhodes (1978 and 1981) were mainly responsible for the modern day concept of Data Envelopment Analysis (DEA). The first paper introduced the ratio form of the DEA and because of similarities to the definitions of efficiency used in the Engineering and Science disciplines, it had some enhanced interpretative powers, and so, was quickly embraced by some quantitative researchers in the field of Management Science. The second paper coined the name "Data Envelopment Analysis ( DEA )" and used the duality relations and computational power of Linear Programming to develop the CCR model and its projections to evaluate programs such as the landmark " **Program Follow Through.**" The analysis of this program initiated the identification of the difference between Program Efficiency and the way a program is managed, that is, the distinction between Program and Managerial Efficiencies. This program was a large-scale social experiment in public schools education, it was a Federally sponsored program that was charged with providing remedial assistance to educationally disadvantaged primary school students The design was to test the advantages of Program Follow Through (PFT) students relative to the designated NFT (Non Follow Through) counterparts in various parts in the United States. The intentions of this program was to provide a general set of concepts and methods that can be applied to a variety of public programs where profit, cost and like considerations were not directly applicable. The suggested superiority of the PFT failed to be validated in the illustrative application. However, the DEA approach pointed to the need for the additional possibility of new approaches obtained from a PFT-NFT combination, which may be superior to either of them alone. This study did not achieve its intended aim, but merely laid the foundations for further work using the newly developed DEA procedure. In fact, upon in depth scrutiny of the paper, I am left to believe that more time and energy were spent on the set up of definition of terms for the further understanding of the DEA and the efficiency determination, than on the application of the principle and procedure. The researchers of this landmark study collected data on 11 outputs but used only 3 and further had information on 25 inputs but used 5 in the study. Seventy sites were examined in this study and from the rule of thumb, that was used later in this study to determine the number of input/output variables that were suitable for a number of units investigated, the study was not handicapped by a limited number of DMU's for the 3 outputs and 5 inputs selected for the study. Adequate data was collected to thoroughly characterize the cohort of third grade young children but too little of this data was used in the model which lead to a suspicious shadow to be casted on the results of the study.

Actually, the study did not achieve the goal or test the hypothesis it had set out to prove. I strongly believe that an analysis of the sensitivity of the results to changing input and output variables should have been undertaken. The researchers would have found the most effective 5 inputs among the 25 for which data was collected and the most sensitive 3 outputs from the 11outputs. These selected input/output variables would have given the study better results. Another issue could have factored in the inability of the model to achieve its goals was that of the subjectivity of the researchers. The strong public scrutiny under which this study was placed gave the researchers the proverbial cold feet in reporting or finger-pointing the potential ills of the Elementary School System. Who was directly or indirectly funding this research was a very poignant question to be asked when a critical perspective of the study was taken. This study was Federally funded, which meant that the study had no allegiance to any particular State and was free to report all the findings and results without any potential reprisal from any State agency. However, the magnitude of this study and the importance and the applicability of the results should have been sufficient to force the researchers to " Bite the Bullet" and include all the potent input/output variables and analyze the results without any biases. It was my belief that the researchers were reluctant to pinpoint waste and administrative inefficiencies in the system run by the people who sponsored the research. They ( the researchers) were more interested in maintaining good relations with the Department of Elementary Education and continuing their development of efficiency analysis. This is opposite to the case where a dissertation is written and the student is directed to discuss all the results of the study.

. Thorogood (1983) in a dissertation on the application and utilization of DEA for decision support in the administration of instructional programming for an urban community college, analyzed twenty-two (22) community colleges using the DEA to analyze Occupational Instructional Program. The aim of the study was to address the problems found in urban community colleges where occupational instructional programs produced different quantities of identified outputs and consumed varying quantities of inputs. To do this study he used: student contact hours, number of fulltime instructional staff members, square footage allocated to facilities and expenditure as the input variables and selected revenue earned, number of student completers employed directly in career areas in which they were trained and employer satisfaction with the program as output variables. He found 8 efficient units and 14 inefficient ones. The highest grouping of efficient units was in the business content area, while the highest number of inefficient units were in the Health related, Engineering and Industrial Technologies areas. Six new proposed programs were analyzed and from the results the college administration opted to close some existing programs to start up the new programs. DEA provided a strong decision making tool for the Administrators. This research was completed very similar to the present study undertaken. The major difference between Thorogood's work and the present study was that Thorogood used Occupational Instructional Programs as the DMU's as opposed to individual colleges as DMU's in the present study. There were minor differences in the input/output variables list but overall

Thorogood's analysis gave the present study a level of validity and endorsement because of its similarity in research environment. Thorogood's research was free of any outside influences that might have hindered the objective reporting of all the results because it was completed at the University of Texas, School of DEA and Cybernetics.

Later in 1986, Desai produced a dissertation that measured efficiency with an application of educational productivity. The thrust of this work was devoted to program evaluation on policy issues on compensatory education programs in elementary schools. Desai used DEA to develop indices of relative effectiveness and resource utilization efficiency of schools of the Philadelphia District. Desai used these indices in the study to overcome problems, resulting from the use of Regression Analysis, in the measurement of marginal improvement, in particular, the effects of intervention of a compensatory education program. Apart from the application aspect of the study, Desai developed new methodologies. The first was a development of non-radial measure of relative efficiency, the second contributed to a test for the correct partition of data into homogeneous or non-homogeneous groups and the third methodological change was in a reformulation of the DEA mathematical program to allow for random variations in data. Desai explained that in order to obtain a stochastic formulation of the problem there is first need to obtain the data distribution and showed that the lognormal distribution provides a good approximation to the distribution of the ratio of two normal variables. The entire study represented a good number of extensions to existing methodology that furthered the applications of DEA. However, at the writing of this dissertation none of these improvements to existing methodology had surfaced to the top to be included as new methodology for DEA. This was very unfortunate, because the three improvements in the methodology of DEA that were postulated by Desai could have helped to increase the span of applicability of this new tool for the efficiency determination in education and industry as well. A suggested reason for Desai's work not catching the eyes of educational and industrial researchers was that the study did not have the blessings of the DEA gurus at the University of Texas. As subjective as one may think this reason was, this had been the main reason for the selection of many directions in various research work.

At the same time, Justinger(1986) developed an efficiency analysis study for an Ed.D Dissertation. This work was concerned about the level of efficiency with which New York State Community Colleges administer the recommended necessary services for adult students participation. The study using two outputs: 25 and over FTE's divided by total FTE and 25 and over graduates divided by the total graduates and four inputs: counselors per student, tutor hours available to student, child care hours per adult student and special organizations available per student, was focused on 23 community colleges, where six were found efficient, two rated between 90% to 99%, four between 80% to 89%, one between 70% to 79%, two between 60% to 69%, and the remaining had ratings below 60% efficiency. Recommendations were made on those inefficient colleges, those having slack(excesses in Input or Output variables), to be reexamined and reassessed on the slack areas to improve efficiency. As an EdD dissertation, this study was free of the biases of sponsor or governing bodies where the study was done. It is my opinion that outputs could have been better selected to measure the level of efficiency with which the Community Colleges of New York State administered the recommended necessary services for adult participation. Maybe these two ratios used as output variables merely hinted to the level of efficiency but were very nebulous. This work demonstrated the applicability of DEA to the efficiency determination within the community college setting but identify the poor selection of output variables.

Harrison (1988) conducted a study for the Ph.D. dissertation on nineteen universities of the State of California University System. The aim of the study was to determine the technical efficiency and quality of these universities and in doing so, Harrison found that because of the ability of the DEA procedure to handle multiple inputs and outputs variables in the determination of the efficiency of a unit, the method provided a better measure of efficiency than the single input /single output Ratio Analysis most often used to describe university efficiency. The results showed that DEA could be used to evaluate performance of universities along the dimension of technical efficiency and quality, as total performance measurement tools. These results also indicated that all the efficiency scores were nearly equal and the inefficient universities had considerable slack in the faculty input variable of the model. This study added a most attractive dimension of quality to the efficiency determination of the universities. This was never done by any other researcher and I consider this study as a good precursor for efficiency determination studies in higher education..

Ray (1991) analyzed Data on Connecticut Public Schools using DEA to determine Resource Use Efficiency. This work combined DEA with Regression Analysis to determine the relative efficiency of the Public Schools. The results showed that efficiency in utilization of school resource inputs varies with the socioeconomic characteristics of the town. The average level of managerial inefficiency was 12.64 percent. The study concluded that this 12.64 percent measure provides a frame of reference for improvement in the levels of utilization/achievement from existing resources through improved management. This 12.64 percent of managerial inefficiency was low but was very characteristic of the Public Schools in Connecticut at the time of the writing of this dissertation. With the demand for higher levels of accountability by the State Legislature and other endowments that provided funding for special educational projects, the schools were forced to improve.

Later in the same year Banathy (1991) wrote a Ph.D dissertation on performance in Community Colleges using Data Envelopment Analysis. This study postulated that the performance accountability in community colleges is complex because of their diversity and searched for another method to account for the variations in goals and institutional uniqueness in the determination of performance in these community colleges. To alleviate the degree of complexity at these institutions, the evolution and shaping factors of the community colleges were closely examined. In making this analysis, Banathy employed DEA to: (a) take multiple goals into account, (b) categorize educational units into peer groups for comparison and (c) identify the strengths and weakness of individual units relative to their peers. This study highlighted the computational difficulties when using multiple inputs and outputs in the determination of the performance efficiency at the community colleges. It validated the need for a DEA –like procedure to handle the multiple input and outputs and other calculation characteristics of those that could have been handled only by DEA.

W. Puttakul (1994) wrote a PhD dissertation on the applicability of DEA to the measurement of the efficiency of 43 Area Vocational Technical Schools (AVT). Seventeen schools were found efficient and twenty- six were determined inefficient. On an average, the inefficient schools needed to increase the outputs by approximately 24% and decrease the inputs by 7% from the current amounts in order to achieve efficiency.

The following conclusions were drawn about the efficiency of the ATV's and the DEA procedure.

1. For specified Output and Inputs, the AVT's performed at a 90% efficiency level.
2. School improvement policies and plans can be directed by DEA findings.
3. DEA results sufficiently inform individual schools "where they are" relative to the others and where to go in terms of output and input improvement but not sufficiently enough as to help them how to get there.

This research demonstrated the use of the DEA procedure with no hidden agenda by the researchers. The results were direct findings of the study.

In 1994, Lovell, Walters and Wood wrote an article on the Stratified Models of Education Production using Modified DEA and Regression Analysis that addressed non-discretionary input data that is so often omitted in many education analyses. The models fail to show any relationship between student outcomes and variablesas per student expenditure teacher/pupil ratio, teacher education, teacher experience and teacher salaries.

Among all the studies that contributed considerably to the application of the DEA procedure to the efficiency evaluation of institution of higher education, the work by C. Kao in 1994, Evaluation of Junior Colleges of Technology – The Taiwan Case, was validated by a separate study performed by the Government. This study analyzed the departments of Industrial Engineering and Management of eleven Junior Colleges of Technology in Taiwan, under the five categories of: educational goal, instructors, curriculum, equipment and administration. A quantitative method called the Pareto-Optimization, a simpler version of DEA was used to calculate the efficiency of the various programs. The author outlined that there was no surprise that the determinations made in this study coincided with those of the Government of Taiwan, primarily because of the accuracy, reality and the multiple inputs/outputs usage of the DEA method.

So far, most of this review of the literature had concentrated on the dissertations that were developed on the universities campuses in the United States. These dissertations considered were mainly studies done on efficiency evaluations on units of the community colleges using the DEA procedure. However, the use of the DEA method for the determination of efficiency had caught on in other works by researchers in higher education in the UK. Johnes and Johnes (1995) produced a paper to use DEA to investigate the technical efficiency of U.K. university departments of Economics as producers of research. As outlined in its abstract, particular attention was paid to the role of external funding of research as an input to the research process. The data set used was an extended version of the one which informed the 1989 Universities Funding Council (UFC) peer review and the results of Johnes and Johnes' study were compared to those obtained by the Council. The study examined the Economics Departments of 36 universities and colleges where the outputs: papers in academic journals and letters in academic journals were used as measures of research and the only input was the persons-months of teaching and research faculty employed over the five year period of the study. These input and output variables produced only 2 universities on the efficient line, namely Liverpool and London (Birkbeck). An important feature was deduced from the study. When the value of the 'external research grants per faculty member' was introduced as a second input, the number of efficient institutions jumped to 9, namely : Aberdeen, Bristol City, Liverpool, London (Birkbeck), London (UCL), Reading and York universities. By adding a second input variable, teaching, to the first run of the model, 7 universities/colleges remained on the efficient frontier line, they were: Bristol, Cambridge, Liverpool, London (Birkbeck), Reading, Warwick and York universities. The author pointed out from the above observation that if all possible inputs were included in the analysis, all the departments of the respective institutions would likely appear to be technically efficient. The paper went on to say that in assessing the relative efficiency of departments it would be prudent to control for inter institutional differences in inputs which could be easily varied in the short run, like grants and teaching load, but not for those that could not adjust. Hence the study developed a measure of technical efficiency, which provided information about the standards a given department could expect to sustain given that it had the same level of transferable resources as every other department. The writers concluded that from the variation in the number of efficient units as additional inputs were introduced in the study, that checks for the robustness of the results of a DEA study were very essential and that DEA has a positive contribution to make in the development of meaningful indicators of university performance.

In addition to these studies that have employed the DEA methodology, there is a number of others that have critiqued the DEA procedure.

Sexton et al (1986) produced a very informative piece of research, which stressed some shortcomings of the DEA but also suggested some extensions of the procedure to meet the needs of multiple objective functions.

As in most organizations, the price for raw materials and services and other price related questions are always in the forefront of managerial decisions. Although DEA can be used to rank DMU's as far as their technical efficiency, DEA cannot be used to comment on the Price Efficiency of the DMU's. That is, " DEA cannot say whether the DMU's are producing the socially optimum (most highly valued) output mix using the least- cost technologies (Sexton et al pg 28). This research went on to say that Farrell (1957) considered the distinction between technical efficiency and price efficiency and showed that DMU's can be technically efficient but price inefficient. Also, while it was clearly important for organizations to operate in productive efficient manner by maximizing the outputs from given inputs, it was often of more immediate concern for the typical non-for-profit organization that it produced socially beneficial outputs using ever shrinking and increasingly constrained financial resources. In essence, the price efficiency could be more important than the technical efficiency.

Another salient feature of this research was the extension suggested for the DEA procedure when several competing objective functions are present in an analysis. For example, consider a firm that wished to simultaneously maximize profit, minimize the need for expansion investment and control employment. These were considered multiple goals and the normal linear programming procedure was to select one goal to be the objective function and place the remaining goals in the constraint set, where a minimum , a maximum or a targeted level were imposed. However, the postulated goal-programming procedure placed all the goals into the constraint set and proposed a new objective function which was the weighted sum of the deviations of each goal from its maximum, minimum and targeted level. Hence, the solution obtained did not maximize profit, minimize the need for expansion investment, or keep employment constant, but achieved a compromise among the goals based on weights attached to the deviation.

The work by Bessent (1983) served as a source of input and output variables used in this present study. Bessent analyzed 28 Occupational Technical Programs at San Antonio College. Twenty-two of these programs represented decision-making units for administration. Each such unit had an administrative head responsible for supervising teaching staff, curriculum and expenditures. This study had 3 outputs: Output1, revenue earned by contact hours through state funding formula, Output2, the number of students completing programs, and Output3, Employer satisfaction with occupational training of students employed. There were four input variables: Input1, student contact hours generated by each program, Input2, number of full-time equivalent instructors in each program, Input3, facilities allocation as determined by square feet assigned to each program for classroom, office and laboratory use, Input4, direct instructional expenditure in each program. Bessent's study using the CCR model, named after the three initial researchers Charnes, Cooper and Rhodes, found 8 programs efficient. The remaining efficiency values provided an overall summarizing index for all the inputs and outputs and the other results discovered which inputs were poorly utilized and what output levels were necessary to bring the inefficient programs up to an efficient level. Although this study yielded good results, I disagreed with the inclusion of output3, employer satisfaction with occupational training of students employed. This variable was not very reliable: was loaded with individual subjectivity and was difficult to gather from the employer. Hence, I excluded this variable from my output list for the present study and added two different outputs that characterized the community colleges more closely.

An even more critical attack on the DEA procedure came from Goldstein (1990). He wrote, " one of the difficulties with the use of the Data Envelopment Analysis ( DEA) has been the relative obscurity of the Mathematical techniques with which it operates." The paper further outlined the basic make up of the DEA Procedure and with the use of a simple (1 Input and 1 output) example; it attempted to demonstrate the shortcomings of DEA as a tool for the determination of school efficiency. The writing concluded with a very strong statement expounding that it was difficult to see any justification for the use of DEA in the studies of educational efficiency.

Goldstein (1990) is a strong proponent to the idea that the only basis for research in performance determination of schools should be rooted in Multilevel Models. In his critique of the DEA procedure he insisted that there was a need for a functional one to one relationship between the Input and Output variables before the efficiency of a system could be defined. This was opposite to the main tenet of the DEA procedure particularly in the performance assessment of educational institution where the functional relation between resources and products are unknown.

Goldstein's attempt to demonstrate the mechanism of the DEA by using a single input and a single output example was an unfair attack with an oversimplified characterization of DEA which failed to recognize the true applicability of the procedure. One must bear in mind that the DEA procedure was designed for the use of multiple inputs and multiple outputs system without prior knowledge of any functional relationship between the input/output variables. Also, the procedure was rooted in Mathematical Linear Programming, in particular, the Simplex Method with procedures and principles that are widely accepted by the researchers of Operations Research and are therefore both well known (i.e. could hardly be described as depending on techniques of "relative obscurity") and relatively uncontroversial. From Dr. Goldstein shallow and unfounded statements, I strongly believe that he did not make his case with the example he used.

Although the fundamental DEA models (CCR and BCC, to be discussed in the following chapter) have undergone a number of improvements in recent years [ see Lovell (1993) and Seiford (1996)], one of the main criticism faced by researchers using non-parametric methods is the difficulty of drawing statistical inferences.
However, as shown by Grosskoft (1996) more recent researchers have published evidence that they have been relatively successful in finding ways to overcome this

problem. One of the first methods recommended to solve this problem was Regression Analysis. The basic method, which has come to be known as the "Two Step" technique, was to treat the efficiency scores as data or indices and use linear regression to explain the variation of these scores. However, if the variables that are used in the specifying the original efficiency are correlated with the explanatory variables used in the second stage, then the second stage determination will be inconsistent and biased [Deprins and Simär (1989): Simar, Lovell and Vanden Eeckaut (1994)]. Bhattacharyya et al.(1997)postulated that when employing regression analysis in the second step to explain the variation of the efficiency scores, it is likely that the included explanatory variables fail to explain the entire variation in the calculated efficiency and unexplained variation mixes with the regression residuals, adversely affecting statistical inference.

Xue and Harker (1999) have pointed out that the efficiency scores developed by DEA models are clearly dependent on each other in the statistical sense. The reason for this dependency is the well-known fact that the DEA efficiency score is a relative efficiency index, and not an absolute one. Since there is this inherent dependency among efficiency scores, the basic required assumption by regression analysis of independence within the sample, is violated. Hence this development renders the conventional procedure outlined in the literature to be invalid. For this problem these researchers recommended a bootstrap procedure to overcome the problem. This bootstrap is a computer based technique for assigning measures of accuracy to statistical estimates.. Simar (1992) was the first to introduce the bootstrap technique for computing confidence interval for efficiency scores developed from non-parametric frontier methods. Since this bootstrap method has been used to develop an empirical distribution of efficiency scores for each observation in the sample: to derive the confidence interval and a measure of bias for DEA efficiency scores, and further to develop the sensitivity of efficiency scores to the sampling variations of the estimated frontier (Simar and Wilson, 1995)

From 1990 to present, DEA has expanded not only as a tool of educational research, for which it was initially intended, but has founded considerable applicability in various fields of Economics, Social Sciences and Engineering (Cooper, Lewin and Seiford, 1994). The DEA procedure has been acclaimed and will continue to be a valuable educational research tool.

# Chapter 3

# Design of the study

## 3.1 Methodology of DEA

Part of the controversy surrounding the subject of performance measurement in Higher Education focuses on the methods of analysis used. Historically, the assessment of institutions of higher education has relied on statistical methods for the development of performance indicators. This has attracted criticism from both academics and administrators (Athanassopoulos & Shale, 1997). Researchers in education are skeptical of any new methodology for measuring the efficiency of colleges, universities, organizations or agencies, which does not explicitly set forth the same assumption requirements as the traditional methodologies. This natural skepticism requires us to closely scrutinize any proposed methodology. The instant any methodology moves from the laboratory to the field, where it is applied in a policy analytic context, the need for thorough inspection becomes urgent. This was the case with Data Envelopment Analysis (DEA), a linear programming technique that was advanced by Charnes, Cooper, and Rhodes (1978,1981). Irrespective of the in-depth examination done, numerous researchers (Johnes and Johnes, 1995 and Bessent et al, 1983) have found benefits in using DEA methodology for the efficiency determination of not-for-profit organizations like those institutions of higher learning.

The DEA is a multi-input and multi-output linear programming based system used to calculate the relative efficiency of organizations, agencies, and public or private not-for-profit institutions of higher education called Decision Making Units (DMU's). As per the classical definition of efficiency, DEA uses a ratio of a weighted output to a weighted input and permits each DMU to select any weights it wants to use for each input and output. The weights must fulfill the following two conditions for them to be satisfactory for the model. First, none of the weights can be negative. Secondly, the weights must be universal; by that, I mean any DMU, within a given system, should be able to use the same set of weights to determine its own ratio of weighted outputs to weighted inputs. It was generally expected that DMU's will allocate heavier weights on the inputs that were used least often in the analysis and on the outputs that produce most (Sexton,1981). Because these inputs and outputs are not traded on the market, they do not have any costs and prices, and so, these weights should not be confused with economic indicators of value. They are merely a weighting scheme that maximizes the efficiency of the DMU in a Mathematical Linear Programming model.

The efficiency, as determined by DEA, is identical to the Productivity Index as used in the field of Engineering and Economics, and as such, uses the inputs and outputs of a DMU to calculate the level of performance of the DMU being considered.

The model for a DMU can be formulated as a linear fractional program, which can be easily transformed into an equivalent linear program in which the DMU input and output weights are the decision variables. For each DMU a linear program must be solved which provides the set of weights and the measure of the relative efficiency.

As shown by most of the commercial microcomputer software for DEA or Frontier Analysis, as it is referred to in other studies, many more helpful managerial tools evolve from the analysis.

In the determination of the efficiency of a DMU relative to other DMU's within a system, for example, a college within a system of institutions of higher learning, each DMU would use a number of different Inputs (common to each college) to produce an assortment of different Outputs (common to each college). The manner in which the DMU converts the inputs to outputs is not critical to the DEA system and so, there is no error incurred in the selection or even the consideration of a production function between inputs and outputs of a selected DMU. The natural cost and prices of selected inputs and outputs to the DMU may be non-existent for some or all (inputs/outputs), especially when considering public and not-for-profit organizations like institutions of higher learning, where input measures like parental education and socioeconomic status are not traded at a market, and so, do not have costs and prices. While these measures are scarce, and hence of value to society, relative to each other and to other goods and services, their values are unknown and immeasurable. (Sexton, 1981)

Data Envelopment Analysis defines the Relative Efficiency of any DMU as the ratio of the total weighted output to its total weighted input. However, the selection of the weights, for the weighting of the input and output variables, creates a serious problem, since no weight values can be assigned to the inputs or the outputs. The assignment of these weights was the central theme of this method. Each DMU was allowed to select any weights that it wanted for each input and output, on the condition that they (the weights) satisfied certain requirements that have been outlined above.

Before I can put the above discussion into mathematical equations representation, there are certain Linear Programming concepts I must present to bring about a thorough understanding of application of DEA for the determination of efficiency and its use as a managerial tool at various organizations.

It must be understood, from Linear Programming Theory, that each DMU analyzed by a Linear Programming Model produces a Primal Model, and a corresponding Dual Model. An understanding of the relationship between the *Primal* and *Dual* specifications of a Linear Programming problem is essential. The Primal Model maximizes the object function and yields a level of relative efficiency of each DMU participating in the study. The Dual Model constructs a completely different set of variables, has its own set of constraints and its own objective function defined in terms of the input /output variables of the DMUs. The DMU with a relative efficiency of 1 is considered efficient and the inefficient ones have a value less than one. Because this is a relative efficiency based on the performance of the other members of the group, an inefficient DMU can strive toward an efficiency level of 1 by using a linear combination of the input and output levels from a Reference Set of efficient DMUs, to calculate a hypothetical efficient DMU. However, the coefficients of the linear combinations must be found.

If a DMU is efficient, then its Optimal Dual solution will have all dual variables equal to zero except the dual variable corresponding to the DMU itself and an extra variable, both equal to one. However, in the event that a DMU is inefficient, the extra dual variable is equal to the efficiency of that DMU and the other dual variables are the coefficients of the linear combination mentioned in the above. It must be noted that some of the dual variables are equal to zero, and in fact, only efficient DMUs have positive dual variables. Hence, the DMUs to which positive Dual variables are assigned represent the Reference Set, which members are to be used to calculate the hypothetical efficient cousin of the inefficient DMUs. In simpler language, dual variables identify the efficient reference set for any inefficient DMU and also provide the multipliers (coefficient) needed to produce the input and output levels of the hypothetical efficient DMU. The dual variables facilitate the construction of a hypothetical DMU that is perfectly efficient from a previously inefficient DMU (say DMUj, j =1...N, where N represents the number of units ). This hypothetically efficient DMU is a linear combination of the members of the efficient Reference Set for DMUj. Thus, the dual variables produce a managerial tool that tell the analyst how an inefficient DMU should be adjusted to become an efficient one.

From the above description of the Optimal and Dual Model of a Linear Programming System, it is relatively simple to obtain answers for the three research questions of this study. The Optimal and Dual Variables for each DMU would not only provide the efficiency figure of the each DMU but would also determine the variables responsible for the level of inefficiency of the DMU and the actions that can be taken to improve a poorly run DMU.

According to Hussain and Brightman (2000) of the Banxia Software Limited, organizations such as banks, hospitals, airlines, government agencies, local authorities and education institutions, all that have branches that perform the same tasks, use this DEA method to determine the following:

i) Resources allocation

ii) Identification of the "Best Practice"

iii) Identification of the "Poor Practices"

iv) Setting Targets

v) Monitoring efficiency changes over time

vi) Rewards for good performance

vii) Planning site location

## 3.2 Mathematical Formulation of the DEA

This section describes the mathematical formulation of the DEA as developed by Charnes, Cooper, and Rhodes, 1987; Bessent and Bessent, 1980). The CCR model is developed by Charnes, Cooper, and Rhodes and explains the output application side and an input reduction side of the model. The CCR input model is presented below:

Suppose that there are n Decision Making Units (DMUs) to be analyzed, each of which uses m inputs to produce s outputs:

$Y_{rj}$ = measurement of rth value output for decision making unit j; $r = 1, \ldots s$, $j = 1, \ldots n$

$X_{ij}$ = measurement of ith value for decision making unit j; $i = 1, \ldots m$, $j = 1, \ldots n$

$U_{rk}$ = weight for output r to be calculated from the analysis for unit k.

$V_{ik}$ = weight for input i to be calculated from the analysis for unit k

$h_k$ = the efficiency value sought for DMU k.

The objective function is the ratio of the total weighted output of DMUk divided by its total weighted input.

$$\text{Maximize } h_k = \frac{\sum_{r=1}^{s} U_{rk} Y_{rk}}{\sum_{i=1}^{m} V_{ik} X_{ik}}$$

$$\text{Subject to: } \frac{\sum_{r=1}^{s} U_{rk} Y_{rj}}{\sum_{i=1}^{m} V_{ik} X_{ij}} < 1$$

$j = 1, \ldots, k, \ldots, n$

$U_{rk} > 0;\ r = 1, \ldots, s$

$V_{ik} > 0;\ i = 1, \ldots, m$

This ratio model is then transformed into a linear programming model with both **Primal** and **Dual** forms:

**Primal model:**

$$\text{Maximize } h_k = \sum_{r=1}^{s} U_{rk} Y_{rk}$$

$$\text{Subject to: } \sum_{i=1}^{m} V_{ik} X_{ik} = 1$$

$$\sum_{r=1}^{s} U_{rk} Y_{rj} - \sum_{i=1}^{m} V_{ik} X_{ij} \leq 0$$

j = 1, …, k, …, n

- $U_{rk} \leq -\epsilon$; r = 1, …, s

- $V_{ik} \leq -\epsilon$; i = 1, …, m

Where $\epsilon > 0$ is a non-Archimedian (infinitesimal) quantity

**Dual Model:**

$$\text{Minimize } Z_k = \Theta_k - \epsilon \sum_{r=1}^{s} {}^{+}S_{rk} - \epsilon \sum_{i=1}^{m} {}^{-}S_{ik}$$

Subject to: $\sum_{j=1}^{n} \lambda_j Y_{rj} - {}^{+}S_{rk} = Y_{rk}$

$r = 1, \ldots, s$

$$\Theta_k X_{ik} - \sum_{j=1}^{n} \lambda_j X_{ij} - S_{ik} = 0$$

$i = 1, \ldots, m$

$\lambda_j,\ {}^{+}S_{rk},\ {}^{-}S_{ik} \geq 0$ for all j, r, and I

Where:

$Z_k$ = reciprocal of $h_k = 1/h_k$

$\lambda_j$ = weight for j th DMU calculated from analysis

${}^{+}S_r$ = slack for r th output

${}^{-}S_I$ = slack for i th input

In the event we wanted to also consider the increasing or decreasing returns to scale, we would employ the BCC model (Banker, Charnes, and Cooper, 1984).

**Primal model:**

Maximize $h_k = \sum_{r=1}^{s} U_{rk}\ Y_{rk} - W_k$

Subject to: $\sum_{i=1}^{m} V_{ik}\ X_{ik} = 1$

$\sum_{r=1}^{s} U_{rk}\, Y_{rj} - \sum_{i=1}^{m} V_{ik}\ X_{ij} - W_k \leq 0$

$j = 1, \ldots, k, \ldots, n$

$-U_{rk} \leq -\epsilon;\ r = 1, \ldots, s$

$-V_{ik} \leq -\epsilon;\ i = 1, \ldots, m$

where $\epsilon > 0$ is a non-Archimedian (infinitesimal) quantity

**Dual Model:**

$$\text{Minimize } Z_k = \Theta_k - \in \sum_{r=1}^{s} {}^{+}S_{rk} - \in \sum_{i=1}^{m} S_{ik}$$

Subject to: $$\sum_{j=1}^{n} \lambda_j Y_{rj} - {}^{+}S_{rk} = Y_{rk}$$

r = 1, …, s

$$\Theta_k X_{ik} - \sum_{j=1}^{n} \lambda_j X_{ij} - S_{ik} = 0$$

i = 1, …, m

$$\sum_{j=1}^{n} \lambda_j = 1$$

$\lambda_j$, ${}^{+}S_{rk}$, ${}^{-}S_{ik}$ $\geq 0$ for all j, r, and I

Where:

$Z_k$ = reciprocal of $h_k$ = $1/h_k$

$\lambda_j$ = weight for j th DMU calculated from analysis

${}^{+}S_r$ = slack for r th output

${}^{-}S_I$ = slack for i th input

## 3.3 College Accreditation

Before the Community Colleges of this System can be evaluated, that is, given a performance assessment rating compared to their peers, it is very important to ensure that these institutions are provided with the necessary resources to educate students and to create the crucial factors that would foster a good learning environment for these students. This process would place all the colleges on an economically equal scale (equal playing field), and so, the efficiency level determined from this study would yield a true measure of the managerial and technical skill of each individual college.

To ascertain that this is done, the Community Colleges of Connecticut are placed under the scrutiny of the New England Association of Schools and Colleges (NEASC). This association is one of the six educational accrediting bodies in the United States, it is a voluntary, non-profit, self-governing organization having as its primary purpose the accreditation of educational institutions. The NEASC team developed the Standards for Accreditation. This team consisted of members of various educational institution as well as prominent members of the public. Hence, these standards represented the combined knowledge of more than two hundred colleges and universities, concerning the crucial elements of institutional quality, and they offer a viewpoint that emphasizes the public purpose of higher education. The NEASC Commission evaluates on a regular basis the effectiveness of its standards and its processes for applying them, and makes the necessary changes as conditions warrant.

Each college of the system acquire its accreditation from NEASC through its Commission on Institutions of Higher Education by demonstrating that it has met the Commission's Standards for Accreditation and comply with its policies. As indicated by the preamble of these Standards; the Standards for Accreditation establish minimum criteria for institutional quality. All colleges are encouraged by the Commission to work toward improving their quality, increasing their effectiveness and continually striving toward excellence. The evaluative processes are designed to establish such improvement.

NEASC uses the following eleven standards as principal areas of institutional activities:

a) Mission and Purposes
b) Planning and Evaluation
c) Organization and Governance
d) Programs and Instruction
e) Faculty
f) Student Services
g) Library and Information Resources
h) Physical Resources
i) Financial Resources
j) Public Disclosure
k) Integrity

The college which meets the Standards (i) has clearly defined purposes appropriate to an institution of higher learning, (ii) has assembled and organized those resources necessary to achieve its purposes, (iii) achieving its purposes and (iv) has the ability to continue achieve its purposes. Further, it must be understood that the Standards are not developed to exclude perceptive and imaginative philosophies that are directed to increasing the effectiveness of higher education. As quoted in NEASC 1992, "Institutions whose policies, practices, or resources differ significantly from those described in the Standards for Accreditation must present evidence that are appropriate to higher education, consistent with institutional mission and purposes, and effective in meeting the intent of the Commission's standards. Furthermore, the existence of Collective Bargaining Agreement in and of themselves, does not nullify institutional or faculty obligations to comply with the standards for accreditation. "

### 3.4 Input – Output Studies

To initiate a discussion on the Input – Output variables that were used in a DEA model, it was necessary to reiterate the most salient feature of the DEA procedure. This states that, DEA makes it possible to deal simultaneously with multiple outputs and multiple inputs, and it does not require prior specification of the functional forms that relate them to each other. This is especially advantageous in the field of higher education where functional relations, such as those between research and student input and plant facilities, are difficult to specify. Similarly, the need for prior specification of weights and like devices is also avoided in DEA. Clearly then, the difficulties faced when using ' total factor productivity indexes' were not encountered when DEA procedure was used. This demonstrated the ease with which the analyst can use input and output variables in the DEA model without having to prep the data or setup the operational variablesfor the model.

It is generally accepted by the researchers of higher education administration, that outputs from the institutions of higher learning can be classified within the following group: (1) education, (2) research and (3) community service. Although the community colleges are not directly compensated for their research activities, their outputs are very present in the education and community service functions. The education output is strongly measured by the total semester credit hours generated and other secondary factors, while the provision of continuing and outreach type of education, as well as healthcare programs and sports and related activities are all considered as the community service output.

On the other hand, Ahn et al (1989) have pointed out that inputs to higher education systems can be found in many more sources than that of the outputs. The following are eleven variables of potential inputs to an institution: (1) Resident Instruction, (2) State Fund Appropriations for Research, (3) General Administration, (4) General Instructional Expense, (5) Staff Benefits, (6) Library, (7) Extensions and Public Services, (8) Physical Plant Operation and Maintenance, (9) Special Items, (10) Major Repair Rehabilitation of building and facilities, and (11) New Construction.

The aim of the selection of the appropriate inputs and outputs variables for the DEA procedure was to ensure that the inputs and outputs used truly characterized the great majority of the operations at the community college and to achieve a level of robustness of the model using the selected variables.

One might conceptualize the fact that the input data should be information with which the researcher cannot interfere, but as outlined by Johnes (1995), the mere ability to select the input variables for a given system is sufficient interference. For a given period, the expenditure portion of the input variables was constrained by the budget. For a fixed quantity of inputs, and a fixed quantity of outputs, the after the fact question was : Was the operation efficient ?? What variable caused it to be inefficient?? In the use of the DEA procedure the mystery lies in the ability of the method to yield an efficiency level without prior determination of a production function between inputs and outputs of the system in question. In the selection of the inputs, I identified the variables that are needed not only to produce graduates but also those inputs that create the learning environment necessary for educating, and hence, maintaining the features of accreditation as mandated by the accrediting body of the region. The sum of the inputs that were represented by a dollar value accounted for 95.99% of the total expenditure of the System on the community colleges. This I considered to be a relatively tight characterization of the colleges' operations by the model and would help to validate the outcomes of the model.

In the development of the output list, there was a considerable amount of difficulty in the characterization of the total deliverability of each community college and the availability of the data for each variable of the output list. I believe that the colleges were given charters to deliver or provide an education to their students, be it, the graduates as well as those who came for one course. This was quantified by the total of the credit awarding grades given for the academic year of 1999-2000 (Fall and Spring semesters). However, a considerable amount of instructional hours were delivered during the winter inter-session, the summer sessions and the continuing education credit and credit-free programs for which a log of these instructional hours or the credit awarding grades was not possible. Hence, the only credible factor that can be used to represent this discrepancy was the accrued revenue for these instructional services as collected by the Continuing Education Department. These quantities were included in the Total Revenue (TOTREV) variable output as discussed in the next section.

In the selection of input and output variables for the model, one can have an overall view of the efficiency as the ratio of the total expenditure to the number of graduates produced as the measure of deliverability of a college. And so, a very simplistic one to one ratio can be used to make some comparison amongst the colleges. This could have sufficed if all the considered inputs were expenditures and all the outputs were number of graduates. However, apart from the expenditure aspect, there were other types of inputs, like the number of square footage of the instructional areas of the colleges and the numbers of instructors, to be considered. The output had in addition to the number of graduates, the numbers of credit awarding grades, percentages of success and the total revenue coming into the college, hence, to determine the efficiency of any of the colleges it was necessary to have a model that could have incorporated multi inputs and multi outputs as the DEA system.

One of the strengths of the DEA is the ability to identify the specific site (Input or Output variable), which is responsible for the inefficient level of operation of a given unit. Hence by dividing the overall expenditure into its individual line items and using these line items as inputs, the analyst can identify the specific part of the overall expenditure that needed to be adjusted for a DMU to achieve an efficient rating. Otherwise, it would have been most prudent to clump all expenditure into one figure.

In this study, the input variables TDIEXP (Instructional Expenditure), TOPP (Physical Plant Expenditure), OEAS (Administrative Services Expenditure) and STUSERV (Student Services Expenditure) were all line items of the overall expenditure figure. These line items were of special interest to the study and their data were readily available, so were included into the list of input variables.

Finally as pointed out by Cooper, Seiford and Tone (2000), DEA allowed both the output and input variables to have the property on Unit Invariance. This means that the variables of the model could have different units without having any effect on the results of the model.

### 3.5 Outputs to the Study

In this section the origin and usefulness of the outputs of the study were identified and described..

The first one code named TOTREV represented the revenue earned by contact hours through the state funding formula. This total revenue received by the colleges includes tuition, fees, credit free programs, contracts and Government Appropriations. Grouped into the Government Appropriations are the Current Unrestricted funds from the State of Connecticut General Fund and Operational Budget along with the Current Restricted funds, which come from the Federal funding, State Appropriations, Private contracts and grants. This TOTREV sum is viewed as a payment the colleges received for the services they have provided. It is the revenue earned for contact hours (TSCHRS) through the State Funding Formula. This revenue figure was obtained from the Connecticut Community College System Statement of Revenues, Expenditures and other charges ( FWRREOB) for the fiscal year 2000.

The second output code named TGANG was the total number of students who completed degree and certificate programs. The aim of this output was to include also the students who have completed enough courses to hold a job in the specific field of study. However, this type of data was not available for the academic year of 1999-2000. This piece of data originated from the Connecticut Community Colleges Report on the Associate Degrees and Certificates Awarded in the period July 1, 1999 to June 30, 2000.

The third output carried the code name SUCPER that represented the percentage of all courses that were taken by the students for the academic year for which they received a credit awarding or successful grade.

The fourth and by far the most difficult to obtain output, were the total successful courses, SUCGRDS, taught by the faculty. The figure represents the total of instructional courses for which matriculating and non-matriculating students did receive a passing grade or a credit receiving grade, that is, a grade from A to D- and P at each college. There were many students who attended the community colleges and did not receive a diploma or a certificate for the courses that they completed. Hence, they were not counted as graduates. They were merely there to take a few courses, to sharpen their skills, change their career or increase their knowledge base. Then to truly measure the deliverability of the colleges, the successful courses of the non-matriculating were added to the successful courses of the matriculating students. This figure had an indication of college/ student success on the teaching to learning interface and was extracted from the data of the Grade Distribution Report at the respective registrars' offices at each college.

Table 3.1

Output Variables used to characterize the Community Colleges

| OUTPUT DESCRIPTION | CODE NAMED | UNITS OF MEASUREMENT |
|---|---|---|
| Total revenue produced by college…Tuition, Government Appropriations and Credit Free ms revenue | TOTREV | Dollars |
| Number of students completing programs, Certificates and degrees | TGANG | Students |
| Percentage of credit awarding grades | SUCPER | Percent |
| Total Credit Awarding Grades | SUCGRDS | Grades |

## 3.6 Inputs to the Study

As mentioned in the section on the accreditation of the colleges in the system, the colleges were encouraged to create a learning environment for the students, and in order to do this, resources must be expended to ensure that adequate instructional area, library facilities, academic and administrative support, instructors and contact hours of instruction were made available for the students.

In this section, I described seven inputs that are used to maintain the learning environment of the colleges.

The first one was code named TSCHRS, which represented the total student contact hours generated by each college. This includes the lecture and laboratory (where applicable) hours for one course per week times the number of students times the number of weeks of instruction times the total number of courses offered in the academic year. This input is used in the State Funding Formula and so it is audited to guarantee that only students enrolled in a course unique to a given program are counted. This figure represents an input to the output revenue (TOTREV) generated and number of graduates (TGANG).

FTEINST was the code name for the second input to the DEA model. This name represented the number of Full Time Equivalent (FTE) Instructors in each college. FTE status was based on a 12 credit hour load for part time staff members. This piece of data was the least ambiguous and considerably easier to obtain.

The third input to the system was code named TISQRFF and designated the facilities allocation of square feet assigned to each college for classrooms, offices, laboratory use and library facilities. These are important variables that the college administrators must keep in sight in order to maintain the respective accreditation level at each college.

The fourth input to the model was the total direct instructional expenditure, TDIEXP, which included salaries for instructors, equipment and instructional supplies. This figure was very simply expressed and easily obtained.

The fifth simple but important input that assisted in the characterization of the college operation is the total operational expenditure for the physical plant, TOPP. This included the annual cost of maintenance of the entire college buildings and grounds, custodial services and any other miscellaneous work done on the respective facilities. It should be noted that the cost for new buildings was not included in this variable. Although new structures were being erected on different campuses during the 1999-2000 academic year, this was not done uniformly at all the colleges in the system.

The sixth input was concerned with the support the students received from both the administrative and academic sides of the college. This figure was code named OEAS that stood for the overhead expenditure for administrative and academic support.

The seventh input to the model was code named STUSERV, which represented the total expenditure on student services outside the regular academic and administrative student support services. This figure entailed the resources expended on college supported student club activities, dances, trips, expenditure on the student activity room and some cafeteria costs.

Table 3.2

Input variables used to characterize the Community colleges.

| INPUT DESCRIPTION | CODE NAMED | UNITS OF MEASURE |
|---|---|---|
| 1. Student contact hours generated by each college | TSCHRS | Hours |
| 2. Number of full-time instructors | FTEINST | Instructors |
| 3.Total Square footage of classrooms, laboratories and library | TISQRFT | Square feet |
| 4. Direct Instructional Expenditure | TDIEXP | Dollars |
| 5. T otal Operational Expenditure for Physical Plant, Grounds and Custodial Services | TOPP | Dollars |
| 6. Expenditure for Academic and Admin. Support | OEAS | Dollars |
| 7. Student Services Expenditure | STUSERV | Dollars |

### 3.7 Non-categorical variables

It is very easy to be absorbed into the belief that once the inputs and outputs of the DEA model characterizes all the tangible variables of the operation of a college, the efficiency results produced by the model would be foolproof and very accurate. However, as Ray(1988) had pointed out, that there are latent parameters hidden in the DMU (college) operations that would hinder the DMU from showing a 100% efficiency.

Up to this point, one assumed that the manager of the DMU that was analyzed could change all the inputs and outputs of the model at the discretion of the analyst. These variables that could be easily varied, were referred to as Discretionary Variables. However, there were input variables that were not or could not be manipulated by the analyst. And these were classified as Non-Discretionary Variables. As cited by Banker and Morey(1986) , such variables were exogenously fixed , like "the age of a store," when using DEA to evaluate the performances of 60 DMUs in a network of fast- food restaurants. To further clarify the issue of these phantom input variables, I considered an explanation from Ray, 1988:

If two firms from the same combination of inputs produce different volumes, the reason has to lie in the fact that there are other inputs or external conditions relevant to the production function which has been ignored, and which are not identical for both firms. The maximum output corresponding to any specific combination of a limited number of inputs explicitly accounted for is realized only when the most favorable configuration of the excluded influencing factors are obtained.

The above quote acknowledged the fact that many other researchers had encountered, the mysterious external input factor over which the analyst or manager had no control.

In the analysis of the twelve community colleges of the system in Connecticut, there were inputs that were exogenously fixed to each college. This was demonstrated as I considered the fact that five of the community colleges were combined with five technical colleges to form five community-technical colleges. The other seven community colleges were merely given the name community-technical without a technical arm. Hence, from the inception of this analysis there were inherent differences between these two groups of the community colleges within the same system. This difference in the basic make up, was the first potential source of non-discretionary or non-categorical inputs to affect the efficiency determination procedure using the DEA that should be considered.

Within the group of combined colleges, for example, Greater Hartford Community College and Hartford State Technical College combined to form what is now Capital Community College. There were cultural differences between the individual colleges, and so, for these two separate entities to operate under the umbrella of Capital Community College, both cultures were adopted and satisfied. This combination introduced a considerable quantity of Non-categorical influencing inputs that was considered when I examined the relative efficiency performance of each college.

There were many more non-discretionary inputs that were considered influencing factors on the analysis. They were as follows: (a) Geographic Jurisdiction (urban, rural, industrial, residential). The Legislature of the State of Connecticut divided the state into twelve regions for which each Community College had first preference for recruiting students. Different types of students come from different part of the state, (b) Socioeconomic background of the students at each college was another difficult factor to measure but very latent and present input to the model.

# Chapter 4

# Analysis of Data

### 4.1 Description of DEA (Frontier Analysis) Model

Administrators are continuously under pressure to improve the performance of their institutions and make the best of available resources. Frontier Analysis can assist in the determination of the relative efficiency of each organizational unit, be it a department, a bank, a branch, a college or anything else that you manage. Frontier Analyst as the DEA model of this study is called, is a Microsoft Windows based efficiency analysis tool, which uses the technique of Data Envelopment Analysis (DEA) to determine the relative efficiency of the units, which perform approximately the same duties. This model is then, best suited for use with organizations or systems like banks, hospitals, colleges, which have various branch units performing the same tasks. As mentioned earlier in this study, the DEA technique originated from the analysis done on not-for-profit public sector organizations where measures other than purely financial were needed to assess performance.

To facilitate the applicative mode of this study, actual development of computer code for the DEA was omitted and a software package from the Banxia Software Company of the UK was used to develop the model.

The description of this model was divided into three main parts: a) **Basic data entry, b) Structuring of the project, c) Analysis of the Results**. To begin the performance analysis of a group of units, it was necessary to identify the two main operators (variables) within the study: namely the Inputs (resources) and the Outputs (products). The mathematical product of model- determined Weights( as discussed in previous chapters of this study) and the corresponding variables yielded the Virtual Inputs and Virtual Outputs. The ratio of the sum of the Virtual Outputs to the sum of the Virtual Inputs for each unit was determined across all the variables, which resulted in the relative efficiency score for each of the units being analyzed.

A comparison between the inefficient units and the benchmark efficient units was made, and so, any potential improvements identified for the low performing inefficient unit, were realistic and highly achievable. The selection of the inputs and the outputs that were used in this efficiency assessment study was extremely important because these variables actually defined the basis on which the efficiency of the units was calculated. Hence, only those input and output variables that are most relevant to the operation of the units should be included in the study.

**A) Basic Data Entry**

Data can be entered into this model in three different ways: a) by pasting data from the clipboard, b) Importing data from disk file and c) manual data entry into the data viewer. The direct data entry into the data viewer was the simplest procedure and was the method selected to enter the data for this study. There was a safety feature for entering data into this model: a blank cell will appear with a pink background to indicate it is empty, however, immediately upon entering a value for a variable the background of the cell changes to blue, yellow or green according to the type of input or output type entered. The Input /Output type can be one of the following:

| | |
|---|---|
| Controlled Variable | A controlled input or output variable was one which the management of the unit has control, and so the analyst can vary the amount of resource used or product produced. |

| | |
|---|---|
| | These were sometimes referred to as the Discretionary Variables. Upon entering this variable value into a cell it turns light green |
| Uncontrolled Input | An uncontrolled variable is one over which the management has no control and so cannot change the level of use or production. These are referred to as Exogenuously Fixed or non-discretionary variables. |
| Output | Outputs are products that result from the processing and consumption of inputs (Resources). These can be goods, services or even, how effectively a unit has achieved its goal. The cell turned light blue once this type of variable was entered. |
| Text | Text fields are not analyzed. They are used to filter units into regions or categories |
| Date | Date text fields are not analyzed. They are used to filter units by periods. |

- Data Envelopment Analysis did not process zeros in the data set. In the event the data contained a zero the system will allow you to replace this zero by a very small number. This feature for selecting to use a small number instead of a zero, is strictly optional and not automatic, so once a zero appeared in the data set the researcher using the DEA would know and would be able to make the necessary changes. The general editing of data in this system followed all the rules of a spreadsheet similar to Microsoft Excel.

Once the model was run with a selected group of units, Input and Output variables, the system allowed the researcher to deactivate any parameter that would alter the results of the next run of the system. Hence, one can chose the variables that can produce the best impact on the determination of the performance of the colleges. However, this was only done during the sensitivity analysis section of the study. This feature, of being able to select effective variables, gave the model the most flexibility. It allowed the researcher to experiment with the data and get a feel for the most important or influential variables and units for the determination of the relative efficiency of each unit in this study.

**B) Project Structuring**

In this section there were two major decisions that were to be made concerning the method by which the data of this model should be analyzed. The first was to choose whether the model should minimize the inputs or maximize the outputs. Since DEA was used to determine the relative efficiency of similar units, the model can do one of the following:

a) For a given level of output of a unit, one can determine by how much can the input of the unit be decreased and still maintain the same level of output. This process is known as Input Minimization.

b) For a given level of input of a unit, what level of output can this unit produce? This is Output Maximization.

For this project, because of the budgeting process at an educational institution, where a finite amount of resources was allocated to perform tasks of varying outputs, the **Output Maximization** option was selected.

The second decision for the structuring of this project was the determination of the type of Return to Scale that should be applied to this model. If the data suggests that there is a linear relationship between the inputs and the outputs of the model, by that I mean, if for a given increase of the inputs values there is a corresponding increase in the outputs and vice versa, then there is a Constant Return to Scale of the data of the model. This data would be best suited by the use of the CCR Model (named after Charnes, Cooper and Rhodes, 1981)

In this research the data showed the expected linearity in the relationship between the values of the inputs and those of the outputs, this was evident because of the high degree of correlation that existed between them. This suggested that a model using a characteristic Constant Return to Scale should be used. The CCR model with the straight frontier line, which was built on the assumption of Constant Returns to Scale, as opposed to the BCC Model (named after Banker, Charnes and Cooper,1981) which had its production frontiers developed by the convex hull of the existing units, was favored for the analysis of the data.

Figure 4.1 and Figure 4.2 below show the graphical representation of the CCR and the BCC models each using six units (A.......F) with one input and one output.

The straight line production frontier which connected the origin to the best performing unit( B) in the set in figure 4.1 , represented the 100% efficiency rating. It must be noted that in the DEA procedure, the efficiency of the units of a system is determined relative to the best performer of the system, as opposed to the comparison made to the average in statistical methods. The line OB represented the best conversion of the input to output within the group of units, and so the efficiency figures of all the other units were determined relative to OB. The CCR model had a lesser number of efficient units as compared to the BCC model, which used the production frontier line formed by the convex envelope of the y-axis, the units and the x-axis. Banker et al , 1984, have shown that the assumption of the CCR or Constant Return to Scale approach is appropriate when all the DMUs are operating at an optimal scale and factors like imperfect competition and constraint on finance may cause a DMU not to operate at optimal scale.

As shown in the Figure 4.2, the BCC or the Variable Return to Scale method would produce more efficient DMUs on the frontier line; however, this model has a unique facility of being able to produce different results as the orientation from Input to Output is varied. These two measures (input and output orientation) are the same in the CCR Model, but do not have the same value in the BCC model. The choice of orientation has both practical and theoretical implications. In some applications, the choice of the orientation is clear, for example, in industries where the emphasis is on cost-control, the natural choice would be an input orientation (Ferrier and Valdmanis, 1996). Quite a few studies have shown an inclination to input-orientated measures because the input quantities appear to be primary decision variables. This argument may not be valid in all industries, because restricting attention to a particular orientation may neglect major sources of technical efficiency in other direction. Nonetheless, I should point out that output- and input-orientated models would estimate the identical frontier and identify the same set of efficient DMUs. Only the efficiency measures associated with the inefficient DMUs may vary between the two models.

To lend a level of completeness and to expose an attractive and useful alternative to the CCR Model of this study, I have included in the Appendix F a DEA run on the variables using both the input and the output orientation in the BCC model. The results of the BCC Model were not very surprising because BCC Model uses a convex frontier line 0n which many more DMUs ( as compared to the CCR Model ) were able to attain the 100 % efficiency. In this case the model had eleven efficient units and one was tagged as inefficient. Northwest Community College, which was deemed inefficient with the CCR Model, was again determined to be inefficient (92.56 %) by the BCC Model. A summary of the results is presented in Appendix F.

Figure 4.1 Production Frontier Lines for the CCR Model

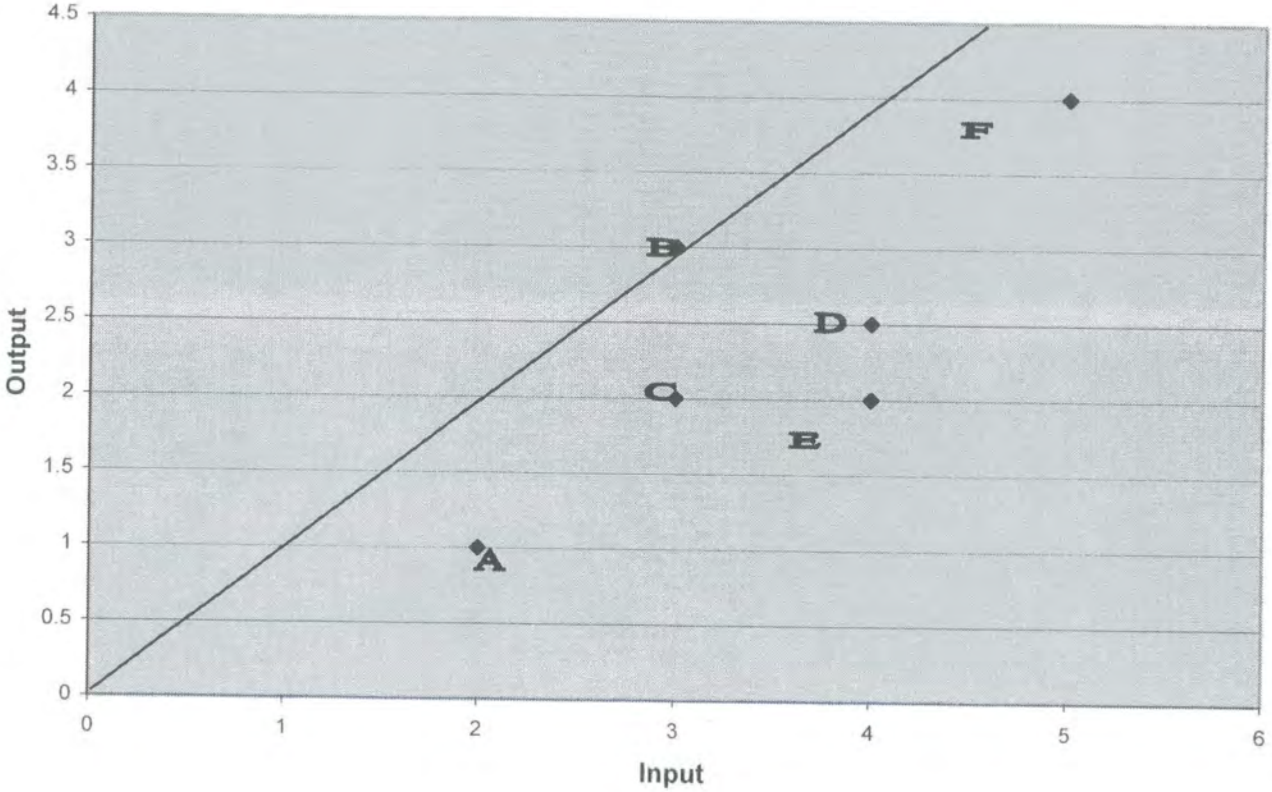
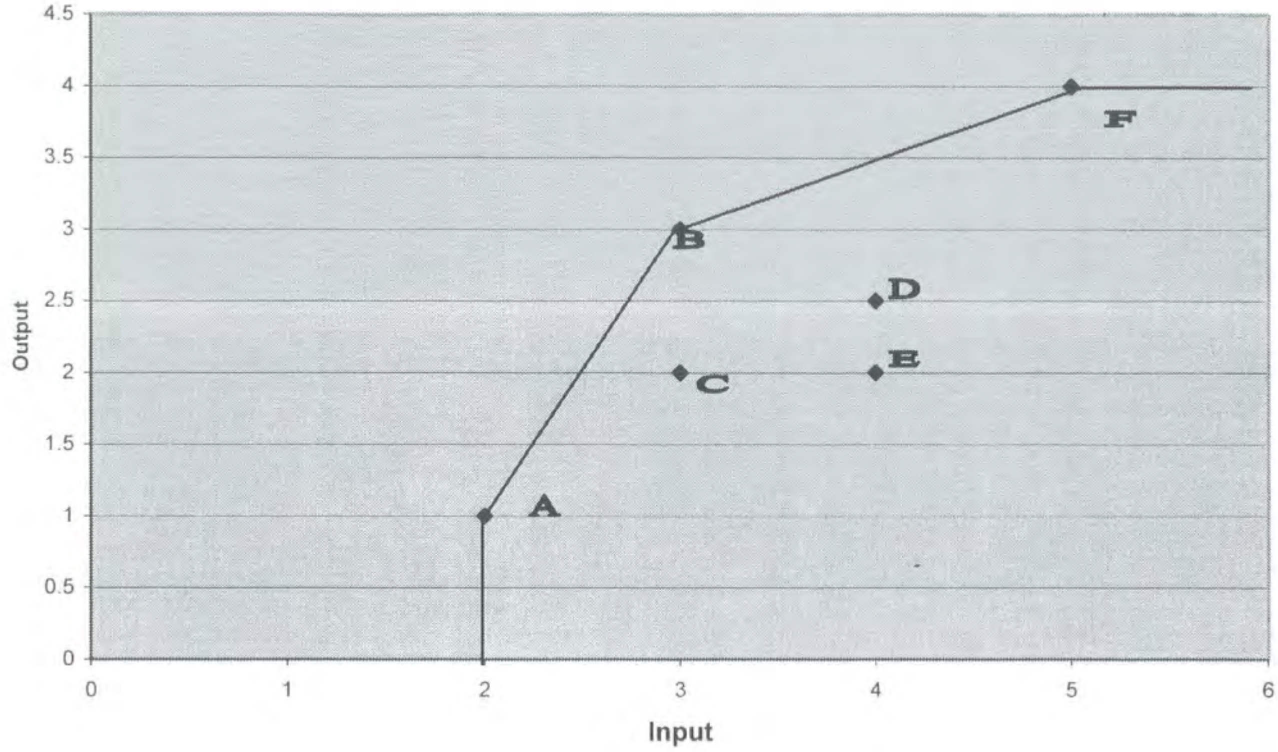


Figure 4.2 Production Frontier Lines for the BCC model




**C) Results of the Model**

The model yielded a considerable amount of important information that assisted in answering the three research questions set out by this study. From the model analysis the following was made available:

i) Main score display – This is the efficiency scores that have been calculated for each of the units, which were active in the dataset.

ii) For each active unit of the study the model calculated: Potential Improvement, Reference Comparison, Reference Contribution and Input/Output Contributions.

## 4.2 Analysis of Model Data

The selection of the inputs and outputs that were used in the efficiency assessment of these community colleges was particularly important, and it must be reiterated, that they defined the basis on which the efficiency of these units (colleges) were assessed. Hence, only those inputs and outputs that were most relevant to the function and characterization of the units were included in the analysis.

In the previous chapter I recognized seven inputs, which I strongly believed, characterized the operations of a community college of this system, from the input end. And although all the data was collected for these input variables, as shown in the Appendix section of this study, all were not included in the study because of the high level of correlation that existed between these input variables. The table that followed demonstrated the level of correlation that was observed between the Input variables. It was very important to acknowledge the fact that the number of units and the number of input and output variables that could have been used, handicapped this study. As developed by Seiford et al (2000), in the study of Statistics and other empirical oriented procedures, there has been a problem involving the degrees of freedom, which was compounded in DEA because of its multiple use of Linear Programming in the determination of relative efficiency of the units. In DEA, the number of degrees of freedom increased with the number of units and decreased with the number of inputs and outputs. A **rule of thumb** that provided rough guidance for this study was:

$$\mathbf{N \geq \max\{m * s , 3(m + s)\}}$$

Where N= number of units, m = number of inputs and s = number of outputs

To make an efficiency determination on the twelve units of this study, the number of input/output variables must meet or be in close proximity to the criterion set by the rule of thumb. The original number of these variables has already been reduced due to heavy correlation that existed between these variables ( as shown below on Table 4.1). Only three inputs and four outputs that merely characterize the operation of the colleges were used. The N value( 12 colleges) is fixed, and so, the m and s values could have been varied to perfectly meet the rule of thumb requirement, but by reducing these values the characterization of the individual college is also reduced. Hence, a compromise must be struck. The decision to use three inputs and four outputs puts the N value within the vicinity ( not equal to ) of the rule of thumb. As shown in the Sensitivity Analysis of Section 4.7, the results of the study can be affected by changing the number of input/output variables, however, the selection of the number of Input/Output variables was kept fixed for the entire study which means that all the colleges were subjected to the same level of scrutiny.

**Table 4.1 XY Correlation between Input variables**

| | TSCHRS | TISQRF | TDIEXP | TOPP | OEAS | FTEINST | STUSERV |
|---|---|---|---|---|---|---|---|
| TSCHRS | 1 | .80 | .95 | .95 | .94 | .14 | .05 |
| TISQRF | .80 | 1 | .88 | .87 | .75 | .53 | .05 |
| TDIEXP | .95 | .88 | 1 | .87 | .91 | .36 | .00 |
| TOPP | .95 | .87 | .87 | 1 | .86 | .18 | .11 |
| OEAS | .94 | .75 | .91 | .86 | 1 | .25 | .04 |
| FTEINST | .14 | .53 | .36 | .18 | .25 | 1 | -0.16 |
| STUSERV | .05 | .05 | .00 | .11 | .04 | -0.16 | 1 |

From the level of correlation that existed between the variables: TSCHRS, TISQRF, TDIEXP, TOPP and OEAS as shown in the above table, the study used one variable, TSCHRS as a surrogate for the five closely correlated input variables. This reduced the input variables list to three: FTEINST, STUSERV and TSCHRS. The number of output variables was the lowest at four: TOTREV, TGANG, SUCGRDS and SUCPER There was insufficient good data to use EAS as a variable and so it was omitted. The Input and Output variables that were not used directly in the study were very important to the study and were used to compare units where the model was not making any direct comparisons. These variables were carried in the tables in the Appendix to facilitate discussions on the performance of the individual colleges.

In an effort for the DEA Model to adhere to the rule of thumb outlined above, the number of variables was reduced from seven (three inputs and four outputs) to four (two inputs and two outputs ). TSCHRS the Total Student Contact Hours and FTEINST, Number of fulltime equivalent instructors were selected as inputs while, TOTREV, Total Revenue produced by the college and TGANG, the number of students completing degrees and certificates, were used as output variables to the model. Since the number of units in the system was fixed at twelve, the only other alternative to bring the analysis within the rule of thumb was to change the number of variables. By reducing the number of variable the model further lost its ability to characterize the operations at the community colleges.

The results showed ten colleges were inefficient and two efficient and the scores obtained by the individual colleges are quite different. The table below shows a comparison of the efficiency scores obtained from the model when seven variables were used versus four variables.

**Table 4.1.1 Comparison of Efficiency Scores with Different number of variables**

| UNITS (Colleges) | Score w/ seven Variables | Score w/ four Variables |
|---|---|---|
| Quinebaug Valley | 100.00 | 97.34 |
| Asnuntuck | 100.00 | 100.00 |
| Middlesex | 100.00 | 87.43 |
| Capital | 100.00 | 100.00 |
| Housatonic | 100.00 | 85.81 |
| Manchester | 100.00 | 81.10 |
| Gateway | 100.00 | 86.29 |
| Three Rivers | 95.23 | 85.00 |
| Northwestern | 91.38 | 90.66 |
| Tunxis | 90.01 | 90.01 |
| Norwalk | 86.12 | 85.62 |
| Naugatuck Valley | 73.92 | 90.66 |

### 4.3 Analysis of Model Results

Two separate software systems: Banxia Software Analysis and Data Envelopment Analysis by Seiford et al, were run for this analysis. Both systems developed the same number of efficient and inefficient units in the college system

The analysis of the results developed three phases, in which each phase provided an answer to the following research questions of this study:

A. How do the colleges of the Community College System of Connecticut compare to each other regarding their levels of efficiency?

B. What conditions may account for the differences in the level of success within similarly efficient colleges?

C. What factors or constraints create the varying scores among inefficient? Colleges?

The first research question:

**How do institutions of the Community College System of Connecticut compare to each other regarding their levels of Efficiency?**

This research question was addressed directly by the results of the model, that showed seven of the colleges had a 100% efficiency and the remaining five colleges of the system were below the 100 % efficiency level. For the period 1999 - 2000 and only that period, Quinebaug, Asnuntuck, Middlesex, Capital, Housatonic, Gateway and Manchester Community Colleges demonstrated a performance level of 100% efficiency. This determination was based on the following variablesof the DEA Model: Total student contact hours, TSCHRS, the number of full time equivalent instructors, FTEINST, the expenditure on student services, STUSERV, the total number of graduates, TGANG, the total credit awarding grades, SUCGRDS, the total revenue that was generated by the colleges, TOTREV and the percentage of credit awarding grades given at the college, SUCPER. Based on these variables and only for the period 1999-2000, the model showed that Northwest, Naugatuck, Tunxis, Three Rivers and Norwalk Community Colleges demonstrated less than 100% level of efficiency. This data is presented in Table 4.2

## TABLE 4.2 EFFICIENCY SCORES

| UNITS (Colleges) | Score w/ seven variable |
|---|---|
| Quinebaug Valley | 100.00 |
| Asnuntuck | 100.00 |
| Middlesex | 100.00 |
| Capital | 100.00 |
| Housatonic | 100.00 |
| Manchester | 100.00 |
| Gateway | 100.00 |
| Three Rivers | 95.23 |
| Northwestern | 91.38 |
| Tunxis | 90.01 |
| Norwalk | 86.12 |
| Naugatuck Valley | 73.92 |

Although the model was very discriminating in the selection of the efficient and less efficient units, there were many non-categorical variables that were not parametrically quantified in the input or output lists. The socio-economic factor (which has shown, in Jesson et al, 1987, to have a direct correlation to students' performance) in the given service region for each college varied as there were colleges. The type of the service areas (Rural or Urban) for which the colleges provide a tertiary education was also not factored into the model, the colleges that resulted from the merger of the

Community and Technical colleges and many more non-categorical variables of the educational process at the community colleges, were omitted from the study, mainly due to a lack of good available data, affected the results of the study.

The efficiency score for each unit was further analyzed to determine the dependence of each unit on the input and output variables. This was a very useful indication of which inputs and outputs were *dominant* in the determination of the efficiency score for each unit. However, this did not mean that the other variables were omitted from the study. It was noted that at any instant, if the model had inputs and outputs that were politically important and were not used as dominant part of the efficiency determination of the units, then the model would have been forced to consider these politically influenced input/output variables using a Weighting Facility of the model

To facilitate an analysis of the input and output variables contribution to the overall efficiency of each unit, the following subscripted letters were use to represent the variables:

INPUTS

V1.......... TSCHRS-- Total Student Contact Hours.

V2. ......... . FTEINST – Fulltime Equivalent Instructors.

V3. ......... STUSERV – Expenditure for Student Services.

OUPUTS

U1 ......... TOTREV – Total Revenue form Tuition, Fees and Government Appropriations.

U2. .......... TGANG - Number of Students completing Programs.

U3. ......... SUCGRDS – Total Credit Awarding Grades given by Faculty

U4. .......... SUCPER – Percentage of Successful Grades Awarded

**Asnuntuck College**
**Efficiency 100 %**

| | | | | |
|---|---|---|---|---|
| Inputs: | .85 (V1) | .15 (V2) | 0.0 (V3) | |
| Slacks: | 0 | 0 | 0 | |
| Outputs: | 1.0 (U1) | 0.0 (U2) | 0.0 (U3) | 0.0 (U4) |
| Slacks: | 0 | 0 | 0 | 0 |

Asnuntuck College had an efficiency rating of 100 % and in order to achieve this level of performance, the college relied on 85 % of the 'total student contact hours' and 15 % of the number of 'fulltime equivalent instructors.' This performance also accounted for 100 % of the 'total revenue from tuition, fees and government appropriations' output. This result was quite understandable and reasonable because of the heavy dependence of the Government Appropriations on the student contact hours

. This does not mean that if the other variables were eliminated the same level of performance would be obtained for the unit.

**Capital Community College**
**Efficiency 100 %**

| | | | | |
|---|---|---|---|---|
| Inputs: | 1.00 (V1) | 0.0 (V2) | 0.0 (V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Outputs: | 1.00 (U1) | 0.0 (U2) | 0.0 (U3) | 0.0 (U4) |
| Slacks: | 0.0 | 0.0 | 0.0 | 0.0 |

The 100 % efficiency of Capital Community College was accounted for by 100 % of the 'total student contact hours' input and 100 % of the 'total revenue from tuition, fees and Government appropriations' output variable. It should be noted that although Capital Community acquired an efficient rating it did so using slightly different spread or mix of the input and output variables, as was demonstrated by all the efficient units. This unit showed the dependence on only two variables, which was not a very technically balanced mode of operation of this unit.

**Housatonic Community College**
**Efficiency 100 %**

| | | | | |
|---|---|---|---|---|
| Inputs: | .11 (V1) | .6700 (V2) | .23 (V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Outputs: | 1.0 (U1) | 0.0 (U2) | 0.0 (U3) | 0.0 (U4) |
| Slacks: | 0.0 | 0.0 | 0.00 | 0.0 |

To achieve the 100 % efficiency performance level. Housatonic College used 11 % of the 'total student contact hours,' 67 % of 'number of fulltime equivalent instructors' and 23 % of the 'expenditure for student services' of the input variables. However, the 'total revenue' variable was the only output variable used by the model to achieve the 100 % efficiency. This unit showed a spread in the utilization of the inputs variables but had a single dependence on the total revenue output variable. Nonetheless, this unit can be considered to be operated more balanced than the previous college, that is, there is a dependence on a wider spread of the resources.

**Gateway Community College**
**100 % Efficiency**

| | | | | |
|---|---|---|---|---|
| Inputs: | .718(V1) | 0.09V2) | .282(V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Outputs: | .452(U1) | .336(U2) | .212(U3) | 0.0(U4) |
| Slacks: | 0.0 | 0.0 | 0.0 | 0.0 |

Gateway Community College 100% efficiency achievement was attained differently from the previous units. 71.8 % of the ‘ total student contact hours’ and 28.2 % of the ‘ expenditure for student services’ input variables, plus 45.2 % of ‘total revenue, 33.6 % of the ‘Number of student completing programs’ and 21.2 5 of ‘ total credit awarding grades given by the faculty’, were all responsible for the efficient rating of the college. This demonstrated a balanced unit as far as, the utilization of the resources and the production of outputs.

**Manchester Community College**
**Efficiency 100 %**

| | | | | |
|---|---|---|---|---|
| Inputs: | .774 (V1) | 0.0 (V2) | .226 (V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Outputs: | 0.0 (U1) | .425 (U2) | .575 (U3) | 0.0 (U4) |
| Slacks: | 0.0 | 0.0 | 0.0 | 0.0 |

Manchester Community College was also among the 100 % efficient colleges, where 77.4 % of the 'total student contact hours' and 22.6 % of the 'expenditure for student services' of the input variables were utilized and a 42.5 % of the 'number of student completing programs' and 57.5 % of 'total credit awarding grades given by the faculty; were used to achieve this level of efficiency. As explained later in the study, Manchester

produced the highest number of graduates and the total credit awarding grades given by the faculty, but did not show the balance ( level of combinations) as demonstrated by Gateway Community College.

**Middlesex Community College**
**Efficiency 100%**

| | | | | |
|---|---|---|---|---|
| Inputs: | .635 (V1) | 0.0 (V2) | .365 (V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Outputs: | .682 (U1) | 0 (U2) | .129 (U3) | .189 (U4) |
| Slacks: | 0.0 | 0.0 | 0.0 | 0.0 |

Middlesex Community College achieved 100% efficiency, where 63.5% of the 'total student contact hours' and 36.5% of the 'expenditures for student services' were utilized from the input variables. The model showed 68.2% of the 'total revenue,' 12.9% of the 'credit awarding grades given by the facility' and 18.9% of the 'percentage of successful grades awarded' were also used to attain this level of efficiency. Again, this unit demonstrated the use of a wide spread or mix of the input/output variables as opposed to those that were used by the other units in the study. A phenomenon I referred to as balance or non-dependency on any single input or output variable.

**Northwest Community College**
**Efficiency = 91.4%**

| | | | | |
|---|---|---|---|---|
| Inputs: | .563 (V1) | 0 (V2) | .437 (V3) | |
| Slacks: | 0.0 | 6.705 | 0.0 | |
| Outputs: | .353 (U1) | .647 (U2) | 0.0 (U3) | 0.0 (U4) |
| Slacks: | 0.0 | 0.0 | .51 | 11.07 |

This unit was deemed inefficient by the model with 91.4% performance efficiency, utilized 56.3% of the 'total student contact hours' and 43.7% of the 'expenditure for student services.' of the input variables, and 35.3 % of the 'Total Revenue from fees, tuition and Government Appropriation' and 64.7% of the 'number of student completing programs' of the output variables to acquire this level of efficiency. This college could have increased their outputs by [(1/eff.) – 1], 9.4% and increase the total credit awarding grades given by faculty by .5, without any increase of expenditures.

**Quinebaug Community College**
**100% Efficiency**

| | | | | |
|---|---|---|---|---|
| Inputs: | 0. (V1) | .510 (V2) | .49 (V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Outputs: | .836 (U1) | 0 (U2) | 0 (U3) | .164 (U4) |
| Slacks: | 0.0 | 0.0 | 0.0 | 0.0 |

Quinebaug Community College achieved the 100 % efficiency rating by utilizing 51 % of the 'number of fulltime equivalent instructors' and 49 % of the 'Expenditure for student Services' input variables. The model showed that 83.6 % of the 'total revenue' and 16.4% of 'percentage of successful grades' was used to acquire the efficient status for this unit. The zero weights on the two output variables, showed that Quinebaug Community College could not have depended on the number of students completing programs and the total credit awarding grades given by the faculty, to attain an efficient score.

**Three Rivers Community College**
**Efficiency 95.23%**

| | | | | |
|---|---|---|---|---|
| Inputs: | .725 (V1) | 0 (V2) | .325 (V3) | |
| Slacks: | 0.0 | 5.50 | 0.0 | |
| Outputs: | 0.0 (U1) | 1.0 (U2) | 0.0 (U3) | 0.0 (U4) |
| Slacks: | 2.411 | 0.0 | 1.97 | 52.44 |

Three Rivers was given a performance rating of 95.23 % and considered inefficient, where 72.5 % of the 'Total student contact hours' and 32.5 % of ' the Expenditure for student services' of the input variables were utilized but there was a sole dependence on the number of students completing programs output variable. Had this unit been operated efficiently, this unit could have increased the outputs by 5.0 % without any additional expenditure to the college, also it could have increased the total revenue by M$2.41, the total credit awarding grades by 1.97 and the percentage of successful grades by 52.44 % all without any increase in the expenditure to run this unit. .

**Tunxis Community College**
**Efficiency of 92.80%**

| | | | | |
|---|---|---|---|---|
| Inputs: | .877 (V1) | 0.0 (V2) | .193 (V3) | |
| Slacks: | 0.0 | 5.78 | 0.0 | |
| Outputs: | .717 (U1) | 0.0 (U2) | .283 (U3 | 0.0 (U4) |
| Slacks: | 0.0 | 24.0 | 0.0 | 57.62 |

The model adjudicated this unit as inefficient with its 92.8 % efficiency. The unit relied on 87.7 % of the total student contact hours, 19.3 % of the expenditure for student services and zero dependence on the number of full time equivalent to achieve this level of efficiency. The college also depended on 71.7 % of the total revenue and 28.3 % of the total credit awarding grades given by the faculty to attain the 92.8 % efficient level. However, this unit could have increased the level of production of its outputs by [(1/eff.)-1] that is, 7.75 % without any further increases of the expenditure to run the college. The slack of 5.78 on the number of full time instructors input variable indicated that this unit could have reduced the number of fulltime instructors by 6 and still achieves the 7.75 % increase on the output variables. This college could have boosted the number of graduates by 24 and increased the percentage of successful grades by 57.62 % without increasing the expenditure.

**Naugatuck Community College**
**73.9 % Efficiency**

| | | | | |
|---|---|---|---|---|
| Input: | .134(V1) | .866(V2) | 0.0(V3) | |
| Slacks: | 0.0 | 0.0 | 0.0 | |
| Output: | .03(U1) | 0.0(U2) | 0.0(U3) | 0.0(U4) |
| Slacks: | 0.0 | 23.036 | 3.090 | 71.71 |

Naugatuck community College was classified by the study as an inefficient unit. With 73.9 % efficiency, this unit could have increased the output scores by at least 35.3 % without any additional expenditure to this particular college. The weights or multipliers on the three inputs reflect the relative influence of each input in the determination of the efficiency score. This showed that 13.4 % of the 'total student contact hours' and 86.6 % of the number of ' fulltime equivalent instructors' were both responsible for this unit not having a lower efficiency score than 73.9 %. The zero weight on the ' Expenditure for student services' input variable demonstrated the fact that this unit could not have depended on this variable to give the unit such an efficiency score. It must be reiterated that if Naugatuck had merely two input variables, this unit would have performed worse than the 73.9 % efficiency score.

When the Slacks on the output variables were examined, they indicated that Naugatuck could have increased the number of graduating students by 23 beyond the across the board 35.3 %, without any additional expenditure to the unit.

**Norwalk Community College**
**90.64 % Efficiency**

| | | | | |
|---|---|---|---|---|
| Inputs: | 1.00(V1) | 0.0(V2) | 0.0(V3) | |
| Slacks: | 0.0 | 41.45 | 1.053 | |
| Outputs: | .877(U1) | 0.0(U2) | .123(U3) | 0.0(U4) |
| Slacks: | 0.0 | 248.0 | 0.0 | 185 |

The model showed that this unit depended wholly on the 'Total student contact hours' input variable and 87.7 % of the 'Total revenue' and 12.3 5 % of ' total credit awarding grades given by the faculty' to achieve the 90.64 % efficiency rating.. A 10.34 % increase could have been acquired on each output without any further expenditure from this unit. This college could have reduced the number of full time equivalent instructors by 42 and decreased the expenditure for student services by M$ 1.053 and still acquire the across the board 10.34 % increase. Norwalk Community College could have also could have also boosted the number of graduates by 248 and increased the percentage of credit awarding grades by 185%. after the increase of 10.34 % on the four outputs.

The second research question:

**What conditions may account for the differences in the level of success within similarly efficient colleges?**

Although a large percentage of this question was answered in the response to the first research question, an attempt is made here to further explain differences that were present in the efficient colleges. As was previously mentioned, Asnuntuck, Capital, Housatonic, Manchester, Middlesex, Gateway and Quinebaug Community Colleges all demonstrated a level of efficiency of 100%. To examine the differences in consumption of the resources and the production of the output variables selected in this study, I made a side-by-side comparison of the efficient units using all the variables of the efficient units of the model. Table 4.3 shows the data of this comparison.

**TABLE 4.3 COMPARISON OF THE EFFICIENT COLLEGES**

| Variables | Asnuntuck | Capital | Gateway | Housatonic | Manchester | Middlesex | Quinebaug | Multi-Fact |
|---|---|---|---|---|---|---|---|---|
| TSCHRS | 2.3 | 4.9 | 6.2 | 5.4 | 8.3 | 3.3 | 2.1 | 10K hrs |
| TISQRF | 6.4 | 17.7 | 15.7 | 10.3 | 10.3 | 7 | 3.8 | 10K ft^2 |
| TDIEXP | 3.1 | 8.9 | 10 | 6.8 | 10 | 4.5 | 2.4 | $10K |
| FTEINST | 22 | 67 | 95 | 57 | 106 | 38 | 21 | Instructor |
| TOPP | 0.67 | 1.3 | 1.4 | 1.3 | 1.7 | 0.72 | 0.65 | $1M |
| OEAS | 3.6 | 6.43 | 6.65 | 5.71 | 10.14 | 2.33 | 3.24 | $1M |
| STUSERV | 1.58 | 1.90 | 2.53 | 1.89 | 2.89 | 1.43 | 1.34 | $1M |
| TOTREV | 9.52 | 21.6 | 22.82 | 19.48 | 27.03 | 12.31 | 8.52 | $1M |
| TGANG | 197 | 292 | 393 | 286 | 577 | 155 | 127 | Graduate |
| SUCGRDS | 6.3 | 7.5 | 15.62 | 14.39 | 18.77 | 7.41 | 4.49 | 1K Grade |
| SUCPER | 80.5 | 38.93 | 76.2 | 74.24 | 73.32 | 72.96 | 74.24 | Percent |

TSCHRS --- Total student contact hours
TISQRF --- Total instructional Area Footage
TDIEXP --- Total Direct Instructional Expense
FTEINST --- Full Time Equivalent Instructors
TOPP ------ Physical Plant Expenditure ( Grounds+Building Maint. + Custodial)
OEAS ------- Overhead Expenditure for Administrative and Academic Support
STUSERV --- Expenditure for Student Services
TOTREV ------ Total Revenue ( Tuition, fee,Gov't funding and credit free programs )
TGANG -------- Total number of graduates
SUCGRDS ----- Credit awarding grades
SUCPER -------- Percent of Successful grades

The most direct indicator of the provision of a quality education by each institution was measured by the number of graduates being produced (TGANG) and the quantity of credit awarding grades (sucgrds) given out at any one time. These two factors determined both the quantity of education received by matriculating and non-matriculating students.

Hence, as indicated in the table above, Manchester Community College, by producing 577 graduates and providing 18,770 credit awarding grades , appeared to be the most diligent in the efficient group. Gateway Community College was second by having 393 graduates and providing 15,620 credit-awarding grades for the service area of Greater New Haven Metropolis. It should be noted that there was not a direct relationship between the number of graduates and the number of credit awarding grades given at any college. This was clearly pointed out by Capital Community College and Housatonic Community College: Capital produced 292 graduates and provided 7,500 credit awarding grades while Housatonic had 286 graduates but provided a much higher 14,390 credit awarding grades which indicated that Housatonic had a greater percentage of non-matriculating students. A similar potential for providing an education to the non-matriculating students existed between Middlesex and Asnuntuck where although Middlesex had only 155 graduates compared to 197 graduates at Asnuntuck, Middlesex provided 7,410 credit-awarding grades.

Upon further inspection of the data within this efficient group, Manchester Community College used twice as much of the OEAS – Overhead Expenditure for Administrative and Academic Support—than any of the efficient units. However, the model did not recommend any potential improvement for the relative efficient units of the study.

Third research question:

**What factors or constraints create the varying score among the inefficient colleges**

The remaining five colleges, Three Rivers, Tunxis, Norwalk, Northwest and Naugatuck Community Colleges were given an inefficient rating on the basis of the variables of the model for the period 1999-2000. The following is the rating of these colleges: Three Rivers --- 95.23 %, Northwestern ---- 91.38 %, Tunxis --- 90.01 %, Norwalk --- 86.12 % and Naugatuck --- 73.92 %. The individual analysis of the colleges done in the response to the first research question adequately described the differences and shortcomings of the inefficient units of this study.

For each college in this group the model presented the weighting factors that depicted the level of dependence of the performance assessment on the various input and output variables and the percent or quantity of potential improvement of each variable that was necessary to bring each unit up to 100 % efficient. In essence, the values of the variablesthat create the varying scores of efficiency can be closely examined. In many cases the model requested that the number of full-time equivalent instructors, FTEINST, be reduced, and the total number of students completing the programs, should be increased, in order to achieve a 100% efficiency level. Eighty percent of the time, the total revenue (TOTREV) brought in by the units of this group was adequate and needed no augmentation to reach the efficient frontier. Since TSCHRS was a surrogate for TSCHRS, TISQRF, TDIEXP, TOPP and OEAS, and the model did not call for the reduction or addition to TSCHRS, there was no need to examine the members of this surrogate group for changes where they were possible.

TABLE 4.11 COMPARISONS OF INEFFICIENT UNITS

**( as per Banxia Frontier Analysis)**

| COLLEGES | Three Rivers | Northwest | Tunxis | Norwalk | Naugatuck |
|---|---|---|---|---|---|
| Variable | Act. Tar. PI | Act. Tar. PI | Act. Tar. PI | Act. Tar. PI | Act. Tar. PI |
| STUSERV | 3.14 2.99 -4.77 | 1.81 1.65 -8.62 | 2.96 2.51 – 15.13 | 6.46 2.94 –54.5 | 4.71 3.48 –26.1 |
| FTEINST | 77 68 -11.57 | 33 24.03 -27.18 | 58 51. –12.05 | 123 93.8 -23.7 | 129 95.36 - 26.08 |
| TSCHRS | 6.3 6 --4.77 | 2.70 2.47 -8.62 | 5 4.5 -9.99 | 8.2 7.06 -13.9 | 11.2 8.28 -26.08 |
| SUCPER | 72.67 122.6 68.7 | 72.95 83.1 13.87 | 74.1 105.1 41.8 | 74.2 74.2 0 | 73.1 126 .1 72.51 |
| SUCGRDS | 12.96 87.7 577 | 6.21 70.85 1041 | 11.7 80.6 588 | 19.5 29.9 53.4 | 16.5 57.03 246 |
| TGANG | 460 460 0 | 209 209 0 | 3355 335 0 | 394 438.3 11.2 | 487 504 3.5 |
| TOTREV | 19.6 21.9 11.72 | 10.14 10.14 0 | 19.15 19.15 0 | 30.95 30.95 0 | 33.01 33.01 0 |

**Act..... Actual Performance, Tar..... Target, PI. ..... potential percentage performance**

The multiplying factors for each variable are the same throughout this study can be obtained from the above comparison Table 4.3.

## 4.4 Efficient Reference Set

As part of the results of this model and a very salient feature that was characteristic of the DEA system, was the Efficient Reference Set. This set was a group of efficient units against which the inefficient units were compared, to be deemed inefficient. Each inefficient unit had a unique Efficiency Reference Set and so, the units of this Reference Set acted as the benchmark, which the inefficient units should emulate.

The five institutions that received a rating less than 100% efficiency in this study had the following Efficiency Reference Set.

Three Rivers ..................... Asnuntuck and Manchester

Northwest ....................... Asnuntuck, Capital and Manchester

Tunxis ........................ Asnuntuck, Capital and Housatonic

Norwalk ........................... Asnuntuck and Capital

Naugatuck ......................... Asnuntuck, Capital and Housatonic

As was shown in the previous section, Asnuntuck gained its relative efficiency based on 86 % of the TSCHRS variable and 15% of the FTEINST variable. Similarly Manchester's efficiency level had the input/output contributions of 77.4% of the TSCHRS, 57.5 % SUCGRDS, 22.6 % STUSERV and 45 % TGANG. Since the Reference Set of Three Rivers consisted of Asnuntuck and Manchester, the efficiency of Three Rivers should be based on the FTEINST, TSCHRS, STUSERV and TGANG. The model used STUSERV, and TSCHRS, showing that, indeed, Three Rivers needed to emulate similar variables as the members of its Reference Set, to achieve a 100% efficiency rating. Similar analyses were done on the remaining four inefficient units.

## 4.5 Analysis of individual efficient and inefficient colleges

In the analysis and subsequent proposal of guidelines for the performance improvement of the Community Colleges in Connecticut, this study characterized the tasks of these institutions, as far as their academic program offerings, their intended service areas and their individually acquired parameter values that were used in the determination of the efficient and inefficient grouping. In this Section a view of the performance of the colleges was taken from the State Labor Force perspective.

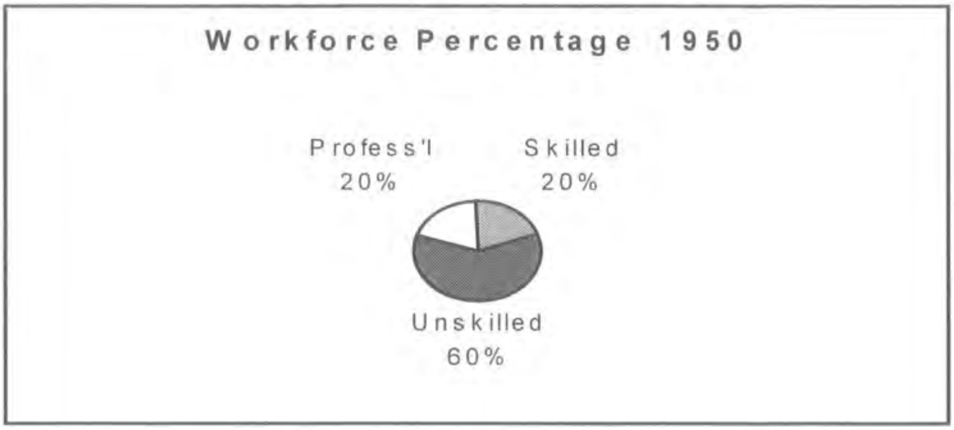
Again this study reiterated the fact that this analysis was done strictly for the period 1999 – 2000 academic year and changes in the operation of the colleges could have occurred to the time of the development of this study.

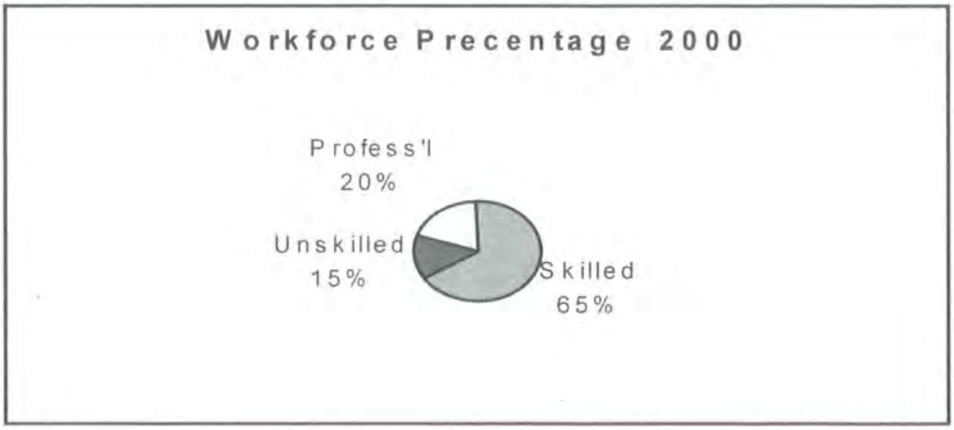
Quoting from the Economic Development Cluster Report: Building Connecticut by Preparing the Workforce of the Future prepared by the System Office Community Colleges of Connecticut:

* In 1950, the Bureau of Labor Statistics classified sixty percent of the jobs as requiring an unskilled labor force. However, in the year 2000, the Bureau predicted that sixty percent of the available jobs required a skilled labor force. The professional categories of employment remained essentially constant, at Twenty percent of the workforce, but the skilled and unskilled categories had made an almost equivalent switch (see Pie chart below).

  The impact of technology forced an increase in the level of skills and the level of education required for most jobs. For career advancement, skills had to be upgraded and retaining lifelong learning was necessary to maintain currency in many fields.

Figure 4.15 Workforce Analysis




From those trends it was evident that in the next five years there would be more job openings in the technical and professional fields than there were workers to fill them. As shown by the Bureau of Labor Statistics, six out of every ten jobs required a technical background. The job growth was concentrated in positions that required training beyond the High School, but not necessarily a four –year degree.

Economic growth in Connecticut in the year 1999-2000 was predicted in six employment areas which were designated as the **Economic Development Cluster**: they were, **Telecommunications & Information Technology, Financial Services, Health Services, High Technology, Manufacturing and Tourism.**

The Economic Development Cluster Report showed the alignment between this cluster and the current programs offered by the twelve Community Colleges of Connecticut, including the Associate Degree curricula, certificate programs, non-credit skill building courses and customized training programs developed for Business and Industry.

As a general outcrop of the Mission of the Community College System, one can say that the curricula offered at all twelve colleges, combining Liberal Arts and Sçiences and career- oriented programs, made a community college education the ideal preparation for the high demand work environment of the 21$^{st}$ century where careers that required: analytical thinking, problem solving, communication, teamwork and lifelong learning, meet the demand of the specific work environment.

Many programs, especially the College of Technology, a transfer curriculum that provided entry at the junior level to the University of Connecticut and Central Connecticut State University, the Water Management and Electrical program options, the Drug & Alcohol Counseling, Fire Technology and Administration and Physical Therapist Assistant programs, were offered system wide through cooperative programs that encouraged resource sharing and convenience for students.

The following section of the study now outlined how the individual colleges attempted to meet the goals of the Workforce of the Future as mandated by the Bureau of Labor of Connecticut, and the factors of their individual efficiency are examined.

**Asnuntuck Community College**, located in Enfield, CT provided a tertiary education to the following service area: East Granby, East Windsor, Ellington, Enfield, Somers, Stafford, Suffield and Windsor Locks, which was described as a farming community raising cattle and growing crops of tobacco and corn. For the period of this study, the college had a total headcount of 3464 students and a Fulltime Equivalent (FTE) of 1488 students. This college offered six programs within the Telecommunications & Information Technology cluster, eight programs within Financial Services, four programs within Health Services, two programs within High Technology, seven programs within Manufacturing and three programs within the Tourism cluster, to a total of thirty programs in the entire college. That was an average size program offering and reflected the low level of industrialization that the service area had undergone. However, this study deemed Asnuntuck as an efficiently operated institution based on all the parameters of the study and the highest contributing factor of the number of fulltime equivalent instructors, FTEINST and the percentage of credit awarding grades, SUCPER given out. During the academic year of 1999-2000, this college did not award a punitive F grade on any of its academic courses, which resulted in the abnormally high, 80.5%, SUCPER value of the study, and propelled the college to an efficient performance standing.

Asnuntuck Community College is located within close proximity of the Somers Correctional Facility and although the towns of the service area did not have a very diverse and ambitious population, the college could enjoy a higher level of prosperity by providing more college level courses to the inmates of the correctional institution. The college would have an opportunity to expand on the program offerings to accommodate the diverse prison population and also increase its revenue base from the state for providing this service.

Asnuntuck Community College, for the period of this study, received a total state appropriation of $9.2 M with which the college produced 197 graduates using 22 fulltime equivalent instructors. This college had the second to the smallest square footage of all the colleges in the system and did a good job in achieving its mission.

**Capital Community College** (previously Greater Hartford Community College and Hartford State Technical College) had a total of 5575 students with 2644 fulltime equivalent students for the academic year 1999-2000. This college serviced Hartford, CT and its five neighboring towns of Bloomfield, Newington, West Hartford, Wethersfield and Windsor. This college had 38 programs distributed among the Economic Development Cluster: Seven programs within the Telecommunications and Information Technology, eight within Financial Services, ten within the Health Services, six within High Technology, six within Manufacturing and one in the Tourism cluster. This college, in my opinion, could have offered a better mix of programs and courses that would reflect the fact that Hartford is the insurance capital of the world.

With the values of the inputs and outputs parameters of this model, this college was given an efficient rating. For the period 1999-2000, the State of Connecticut appropriated $21.6M for Capital Community College with which it produced 292 graduates using 57 fulltime equivalent instructors. The parameters used to determine the relative efficient level of this college, were all within a good range of the values of the other institutions except, the percentage of credit awarding grades given at the college, SUCPER. This parameter had a value 38.93% which was low enough to warrant that some action should be taken to correct this situation.

**Gateway Community College** (previously South Central Community College and Greater New Haven State Technical College) was located in New Haven, CT and serviced the following 12 towns of: Bethany, Branford, East Haven, Guilford, Hamden, Madison, New Haven, North Branford, North haven, Orange, west Haven and Woodbridge. For the academic year 1999-2000 the college had 8075 students with 3834 fulltime equivalent students. This college provided for this service area 63 programs within all the clusters: ten programs within the Telecommunications and Information Technology cluster, eight within Financial Services, eighteen within Health Services, six within High Technology, fifteen within Manufacturing and seven in the Tourism cluster. This college had the largest program offering in the community college system and had a relative efficient rating when compared to the remaining colleges of this system. Although, Gateway had a very respectable program offering, it was evident from its low number of graduates in the field of Biotechnology and because of its proximity to the Biotechnology industry in New Haven, CT, that it should have had more Biotechnology related programs. Gateway Community College was the second of two colleges, which evolved from the merger of two institutions: the Community Colleges and the State Technical Colleges, which received an efficient rating within the system. This college received $22.82M appropriations with which it produced 393 graduates using 95 fulltime instructors. This college did a commendable job in its attempt to achieve its mission.

**Housatonic Community College** was located in Bridgeport, CT and serviced eleven towns: Ansonia, Bridgeport, Derby, Easton, Fairfield, Milford, Monroe, Seymour, Shelton, Stratford and Trumbull and provided twenty nine programs within the Economic Development Cluster: seven programs within Telecommunication and Information Technology, eleven programs within Financial Services, seven programs within Health Services, three programs in High Technology, one in Manufacturing and one in Tourism. This college had a 7578 headcount and 3542 fulltime equivalent students and had 14390 credit awarding grades given out, although there were 286 graduates as compared to Capital 292 graduates for the 7500 grades. This indicated that Housatonic Community College had a large non-matriculating student population: people returning to college to improve their career standing or changing careers, which was part of the mission of the Community College System of Connecticut. Based on all the parameters used in this study, the college received a relative efficient rating and showed a utilization of $19.48 M of State Appropriations to produce 286 graduates using 57 fulltime equivalent instructors. The program offerings for the Health Services and Tourism clusters could have been increased to attract a higher proportion of potential student whom had been laid off from the manufacturing industry of the area.

**Manchester Community College** was located in Manchester, CT and serviced the towns of Andover, Bolton, Columbia, Coventry, East Hartford, Glastonbury, Hebron, Manchester, Mansfield, Marlborough, South Windsor, Tolland, Union, Vernon/Rockville and Willington. For the academic year of 1999-2000, the college enrolled 9783 students with a fulltime equivalent of 5021 students. The college had a very respectable offering of 47 programs within the six Clusters of Economic Development: ten programs in Telecommunications and Information Technology, ten programs in Financial Services, thirteen programs in Health Services, two programs in High Technology, five programs in Manufacturing and seven in the Tourism cluster. This college received an efficient rating from the parameters of this study; it used $27M of State appropriations to produce 577 graduates using 106 fulltime equivalent instructors. Since this model did not show any Potential Improvements (PI) for the efficient units, comparison between the efficient units made by examining the data on Table 4.3, showed that this college used a noticeable $10.14M on the OEAS parameter. This parameter represented the Overhead Expenditure for Administrative and Academic Support and was approximately double any other OEAS parameter value for the efficient units in this study. Apart from this high administrative cost, Manchester Community College did a commendable job in achieving its mission within the Community College System of Connecticut for the period of this study.

**Middlesex Community College** was located in the town of Middletown, CT, enrolled a total head count of 4426 students which resulted in 2079 fulltime equivalent students. This college serviced the towns of Chester, Clinton, Cromwell, Deep River, Durham, East Haddam, East Hampton, Essex, Haddam, Killington, Meriden, Middlefield, Middletown, Old Saybrook, Portland, Rocky Hill, Wallingford and Westbrook, and provided twenty-nine programs within the Economic Development Cluster. The programs were as follow: seven in the Telecommunication and Information Technology Cluster, eight in the Financial Services Area, nine in the Health Services Cluster, two in the High Technology Cluster, four in the Manufacturing Cluster and one in the Tourism Cluster. For the period of this study this college was operated efficiently as per the model and the parameters used. For 18 towns of the service area, the program offering appeared to be very meager. There was a high school in each town and in order to capture a reasonable percentage of those students the program offering should be more attractive. Also because of this college's proximity to the Greater New Haven Area it should have had a larger program offering of Biotechnology related courses to meet the demand of this area.

This college used \$12.31 M of State Appropriations to produce 155 graduates using 38 fulltime equivalent instructors during the academic year of 1999-2000, using the lowest expenditure for administrative and academic support (OEAS) of \$ 2.33 M of the entire study. This was a very commendable job on the part of Middlesex Community College.

**Quinebaug Valley Community College** was located in the Northeast CT town of Danielson and serviced thirteen towns of Ashford, Brooklyn, Chaplin, Eastford, Hampton, Killingly, Plainfield, Pomfret, Putnam, Sterling, Thompson, Windham, and Woodstock. This college provided 26 programs within the Economic Development Cluster: four programs in the Telecommunications and Information Technology Area , ten programs within the Financial Services, five in Health Services, two in High Technology, five in Manufacturing and zero in Tourism. This was a very small program offering fitting for the most sparsely populated area of Connecticut. The college enrolled a total headcount of 2492 students, and had 1261 fulltime equivalent students. During the period of this study this college received \$8.52 M from the State Appropriations with which the college produced 127 graduates using 21 fulltime instructors. The operation of this college was deemed efficient by this study and it was very commendable to see that Quinebaug Community College had the insight to offer Plastic Engineering and Plastic Technology in its Manufacturing Cluster

**Three Rivers Community College** (previously Mohegan Community College and Thames Valley State Technical College) was located in the town of Norwich, CT and serviced 23 towns of Bozrah, Canterbury, Colchester, East Lyme, Franklin, Griswold, Groton, Lebanon, Ledyard, Lisbon, Lyme, Montville, New London, North Stonington, Norwich, Old Lyme, Preston, Salem, Scotland, Sprague, Stonington, Voluntown and Waterford. This college had the largest program offering of 63 programs of the Economic Development Cluster in the Community College System: ten programs in Telecommunication and Information Technology, seven programs in Financial Services, eighteen programs in Health Services, six programs in High Technology, fifteen programs in Manufacturing and seven in the Tourism Cluster. With the two campuses this college enrolled a total headcount of 6900 students from which there were 3403 fulltime equivalent students. This college received $19.59 M from state appropriations with which it produced 460 graduates using 77 fulltime equivalent instructors, which was a very commendable job, however, this study did not deem it an efficiently operated unit. This college received a 95.23 % efficiency rating which was good for a college with this size of program offering. In order to achieve a 100% efficiency rating this study recommended the following: a reduction of 4.77 % of the expenditure on student services, a reduction of 11.57% of the number of fulltime equivalent instructors (from 77 to 68), a reduction of 4.77 % of the total contact hours with the students, an increase of 68.72 % on the percentage of credit awarding grades given out at the college, an increase in the overall number of credit awarding grades and a 11.72 % increase in total revenue coming into the college. In this study the Total Student Contact Hours (TSCHRS) acted as a surrogate to four other highly correlated parameters: TISQRF, TDEXP, TOPP, OEAS and any change in TSCHRS requested by the model indicated that was a need for a change in one or any of the members of this group. These changes were presented strictly as guidelines and many times, when the study gave a specific value increase or decrease in any of the parameters, this indicated that there was need to further investigate of this parameter.

**Northwestern Connecticut Community College** was located in the town of Winsted, CT and provided a tertiary education to twenty towns: Barkhamsted, Canaan, Canton, Colebrook, Cornwall, Goshen, Granby, Hartland, Harwinton, Kent, Litchfield, Morris, New Hartford, Norfolk, North Canaan, Salisbury, Sharon, Torrington, Warren and Winchester. This college had 35 programs within the Economic Development Cluster: seven programs in Telecommunications and Information Technology, six programs in Financial Services, ten programs in Health Services, two programs in High Technology, three programs in Manufacturing and seven programs in the Tourism Cluster. During the academic year of 1999-2000, this institution enrolled a total headcount of 3294 and had 1406 fulltime equivalent students. The college received $10.14 M of State Appropriations with which it produced 209 graduates using 33 fulltime equivalent instructors, which was a good job. However, this college did not get an efficient rating from the study, for the input and output parameters used in the model, this unit was assessed to a rating of 91.38

%. In order to achieve a 100% efficiency rating, the model showed that the college had to: reduce the expenditure on student services by 8.62 %, reduce the number of fulltime equivalent instructors by 27.18 %, reduce the TSCHRS by 8.62 %, increase the percentage of credit awarding grades (SUCPER) by 13.87 % and increase the total number of credits awarded at the college ( matriculating and non-matriculating).The data also showed that the number of graduates (TGANG) and the total revenue coming into the school, TOTREV, were adequate for the period during which this study was undertaken.

**Tunxis Community College** was located in the town of Farmington, CT where it serviced eleven towns of : Avon, Berlin, Bristol, Burlington, Farmington, New Britain, Plainville, Plymouth/Terryville, Simsbury, Southington and Wolcott. The college offered twenty-seven programs within the Economic Development Cluster: six programs in Telecommunications and Information Technology, eight in Financial Services, six in Health Services, two in High Technology, three in Manufacturing and two in Tourism. For the academic year of 1999-2000 the college had a total headcount of 6646 students and a fulltime equivalent of 3050 students, it also received $ 19.15 M of State Appropriations with which the college produced 335 graduates using 58 fulltime equivalent instructors. This was a very commendable job for a growing college with the excessive competition from the neighboring colleges, however, the study did not give this college an efficient rating, it received a 90.01 % efficiency rating relative to the other community colleges of the system. In order to receive a 100 % efficiency rating Tunxis Community College had to: reduce the expenditure on student services by 15.13 %, reduce the number of fulltime equivalent instructors by 12.05 %, reduce the TSCHRS factor by 9.99 %, increase the percentage of credit awarding grades by 41.84 %. The model was comfortable with the number of graduates and the total revenue coming into the college for the period of the study.

**Norwalk Community College** (previously Norwalk Community College and Norwalk State Technical College) was located in the town of Norwalk, CT and serviced ten towns: Darien, Greenwich, New Canaan, Norwalk, Redding, Ridgefield, Stamford, Weston, Westport and Wilton. This college provided forty-five programs in the Economic Development Cluster: nine programs in Telecommunications and Information Technology, eight programs in Financial Services, twelve programs in Health Services, five programs in High Technology, five programs in Manufacturing and six programs in Tourism. This program offering was considered the most balanced in the system. For the academic year of 1999-2000, the college enrolled a total headcount of 10278 students and had 5195 fulltime equivalent students, which was the best showing for the system of the community colleges for the period of this study. This college received $ 30.95 M of State Appropriations and produced 394 graduates using 123 fulltime equivalent instructors. This was a good job done by this college to achieve its mission, however, the model did not award this unit with a 100% efficiency rating. This college received an 86.12 % efficiency rating and in order to climb to a 100% rating the college had to: reduce the expenditure on student services by 54.51%, reduce the number of fulltime equivalent instructors by 23.73 %, reduce the TSCHRS factor by 13.88%, increase the total number of credit awarding grades by 53.44 % and increase the number of graduates by 11.24 %.

The levels of the SUCPER, percentage of credit awarding grades, and TOTREV, total revenue coming into the college, were considered adequate, and so did not need any changes.

**Naugatuck Valley Community College** ( Mattatuck Community College and Waterbury State Technical College) was located in Waterbury,CT and serviced the twenty-two towns of: Beacon Falls, Bethel, Bethlehem, Bridgewater, Brookfield, Cheshire, Danbury, Middlebury, Naugatuck, New Fairfield, New Milford, Newton, Oxford, Prospect, Roxbury, Sherman, Southbury, Thomaston, Washington, Waterbury, Watertown and Woodbury. The college offered fifty-one programs within the Economic Development Cluster: four in Telecommunications and Information Technology, eight in Financial Services, fifteen in Health Services, eight in High Technology, twelve in Manufacturing and four in the Tourism Cluster. For the period of this study, this college enrolled a total headcount of 9375 students and had 4941 fulltime equivalent students, which represented the second highest fulltime equivalent student enrollment for the academic year 1999-2000. Naugatuck Valley Community College received, for the same period, a $33.01 M State Appropriations with which it produced 487 graduates using 129 fulltime equivalent instructors. This college received an efficiency rating of 73.92 % and in order to achieve a 100% rating it had to: reduce the TSCHRS factor by 26. %, reduce the number of fulltime equivalent instructors by 26.08 %, reduce the expenditure on student services by 26%, increase the number of graduates by 3.5%, and increase the percentage of credit awarding grades and the total number of grades given out at this college. The total revenue or appropriations was adequate for the college as determined by the model.

It should be borne in mind that the indication of inefficiency of the colleges was based on the chosen parameters of the model for which there was good selection of available data. However, there are many non-tangible variables in the education production function, this is the function that converts inputs to the educational process into the desired outputs, that are not accounted for in the this model, and so, although the results of the model were good indicators of the level of operation of the colleges, they should be used as guidelines on which the respective administrators should act. These were not meant to be absolute facts that were etched in stone.

## 4.6 Improving the Efficiency rating of the inefficient colleges

The parameters of this study used in the determination of the relative efficiency of the colleges showed that the input variables: STUSERV, FTEINST and TSCHRS (the surrogate for TISQRF, TDIEXP, TOPP, OEAS and TSCHRS) of the inefficient colleges all needed to be decreased by the model determined respective percentages, in order to achieve a 100 % efficiency rating. In essence, these units were consuming too much of the valuable resources. Similarly, the model showed that there were low levels of production of the output variables: SUCPER, SUCGRDS, TGANG, and TOTREV by these inefficient units. This acted as an indicator to researchers and administrators alike, that attempts would have to be made to augment the values of these output variables. Table 4.11 showed the Actual Values, Target Values and Potential Percentage Improvements on the variables of the model for the inefficient colleges. There were three values in the SUCPER variable, which were greater than the maximum value of 100 %, and as mentioned previously, the weighting function of this model could have been used to tweak a weight or two to achieve more desirable results. However, the model was configured to use no artificial weighting of the variables, this would have disturbed dynamic balance and the resulting relative efficiency yield of the model. As mentioned earlier, these values acted as guidelines for the improvement of the operations of the respective colleges.

The following section outlined the actual guidelines for improving the inefficient colleges of the system.

**Three Rivers Community College** : This college received a 95.23 % efficiency rating which was good for a college with this size of program offering. In order to achieve a 100% efficiency rating this study recommended the following: a reduction of 4.77 % of the expenditure on student services, a reduction of 11.57% of the number of fulltime equivalent instructors (from 77 to 68), a reduction of 4.77 % of the total contact hours with the students, an increase of 68.72 % on the percentage of credit awarding grades given out at the college, an increase in the overall number of credit awarding grades and a 11.72 % increase in total revenue coming into the college.

**Northwestern Connecticut Community College :** the college had to: reduce the expenditure on student services by 8.62 %, reduce the number of fulltime equivalent instructors by 27.18 %, reduce the TSCHRS by 8.62 %, increase the percentage of credit awarding grades (SUCPER) by 13.87 % and increase the total number of credits awarded at the college ( matriculating and non-matriculating)

**Tunxis Community College :** . In order to receive a 100 % efficiency rating Tunxis Community College had to: reduce the expenditure on student services by 15.13 %, reduce the number of fulltime equivalent instructors by 12.05 %, reduce the TSCHRS factor by 9.99 % and increase the percentage of credit awarding grades by 41.84 %.

**Norwalk Community College:** in order to acquire a 100% rating the college had to: reduce the expenditure on student services by 54.51%, reduce the number of fulltime equivalent instructors by 23.73 %, reduce the TSCHRS factor by 13.88%, increase the total number of credit awarding grades by 53.44 % and increase the number of graduates by 11.24 %.

**Naugatuck Valley Community College:** in order to achieve a 100% rating this college had to: reduce the TSCHRS factor by 26. %, reduce the number of fulltime equivalent instructors by 26.08 %, reduce the expenditure on student services by 26%, increase the number of graduates by 3.5%, and increase considerably the percentage of credit awarding grades and the total number of grades given out at this college.

In summary of this chapter, the Analysis of Data of the Model, of the twelve community colleges of Connecticut, the study addressed more than the mere analysis of the data of the model. It featured: A Description of the DEA (Frontier Analysis) Model as used by a personal computer system, The Analysis of the Model Data, Analysis of the Model Results, The Inefficient Reference Set, Analysis of the Individual Efficient and Inefficient Colleges, and Improving thee Efficiency rating of the inefficient colleges. The DEA model answered the three research questions of this study. A) How do institutions of the Community College System of Connecticut compare to each other regarding their levels of efficiency. This was done by the direct comparison of the efficiency ratings delivered by the DEA model. Seven colleges were rated efficient and five were given considered inefficient for the period of this study. B) What conditions may account for the differences in the level of success within similarly efficient college. This was achieved by examining the differences in the input and output parameters of the model. Since this model did not indicate any Percentage Potential Improvement for the efficient units, the differences in the level of success of the efficient colleges were determined by the manual comparison the variables of the model for each efficient college. C) What factors created the varying scores among the inefficient colleges. The question of the varying scores of the inefficient colleges was addressed through the Percentage Potential Improvement( PPI) of each inefficient unit. These percentages showed the reduction of resources and the augmentation of educational products needed by each inefficient college to achieve 100 % relative efficiency rating from the model. The different PPI's of each unit were directly indicative of the varying (efficiency ) scores of the inefficient colleges.

It should be noted that although there were five colleges that achieved an efficiency rating below 100 % efficiency , these colleges by no means were considered " dogs" of the system to be berated or targeted for elimination at any time... In the analysis of the inefficient, some congratulatory remarks had to be made to these colleges, not that I did not believe the results of the DEA but there were some good being done at these colleges and there were other non-categorical factors which were not measured by the model, that could have possibly placed them into the 100 % efficiency level of operation. Hence the study could not have been overly harsh, but opted to tread stealthily as the results were presented.

## 4.7 Sensitivity - Validation Analysis of the DEA Model

A. Charnes, W.W. Cooper, A.Y. Lewin, R.C. Morey and J.J. Rousseau initiated the study of Sensitivity Analysis in an article entitled
" Sensitivity and Stability Analysis in DEA" which was published in the Annals of Operation Research in 1985. That work was concerned with the fact that changes in the data of the units of a study altered the inverse matrix used to develop solutions in the Simplex algorithm computer codes. Further research in Sensitivity Analysis was directed along the path of finding algorithms that avoided the use of additional matrix inversions. However, Charnes et al (1992) abandoned that path of the algorithmic exploration and embarked on a metric concept. The idea in that new direction was to use a length or a distance to configure "radii of stability " within which the occurrence of data variations will not alter a unit's rating from efficient to inefficient or vice versa (Seiford et al, 2000). Along the idea of efficiency stability with data variations, the sensitivity check was developed for the twelve units of this study.

The sensitivity analysis of the model results examined the stability or the robustness of the DEA model in order to identify the factors that changed the rating of the units from inefficient to efficient or vice versa, as per the following changes:

a) The most highly compared unit, that is the unit that appeared in the Reference Set as Benchmark to the inefficient units most often ( that was Asnuntuck), was removed from the study. The relative efficiency of the remaining units was then determined.

b) Removal of each variable from the model, for example, TGANG, then the relative efficiency scores of the units were successively calculated.

c) Different variable values were used in the model and the new efficiency score were calculated.

d) The study used a DEA Model developed by Cooper, Seiford and Tone and calculated the efficiency of the units.

Thus, this analysis provided an index of stability of the relative efficiency of the units of the model by measuring the extent to which changes in or the omission of an input or an output variable value, a unit or even the utilization of a different software model, rendered the individual colleges efficient or inefficient.

To lend some validity to the study, a second DEA (Frontier Analysis ) model developed in the US by Cooper, Seiford and Tone (2000) was used to analyze the same data as in the first model. The results of the second model were identical to that of the first and were included in the Sensitivity Analysis Section of chapter 4. To verify some of the findings of the model, an interview was conducted with a senior financial administrator at one of the colleges of the system. This administrator had been in the employ of the college for the past 12 years and had observed the cycles the colleges had undergone during his tenure. He was satisfied by the general trend and the individual results of the colleges proposed by the results of the model, and he was convinced that there were at least five colleges within the system that were being operated at a lower level of efficiency than the others. His choice of low performers based on his administrative markers, was identical to the group of colleges that received an efficiency rating of less than 100 % from the DEA model.

## Table 4.12 SUMMARY OF SENSITIVITY ANALYSIS

| MODEL RESULTS (BANXIA SOFTWARE) | MODEL RESULTS (COOPER, SEIFORD & TONE) | REMOVAL OF ASNUNTUCK (MOST COMPARED UNIT) | **REMOVAL** VARIABLE REMOVED | **OF** RESUTING UNITS EFF. RANGE | **PARAMATER** RATIO NUMBER OF EFF/INEFF UNIT |
|---|---|---|---|---|---|
| QUINEBAUG - 100% | QUINEBAUG - 100% | QUINEBAUG - 100% | TSCHRS | 100 - 64.97 % | 6/6 |
| ASNUNTUCK - 100% | ASNUNTUCK - 100% | MIDDLESEX - 100% | FTEINST | 100 - 71.50 % | 7/5 |
| MIDDLESEX - 100% | MIDDLESEX - 100% | CAPITAL - 100% | STUSERV | 100 - 62.00 % | 3/9 |
| CAPITAL - 100% | CAPITAL - 100% | HOUSATONIC - 100% | TOTREV | 100 - 62.00 % | 5/7 |
| HOUSATONIC - 100% | HOUSATONIC - 100% | MANCHESTER - 100% | TGANG | 100 - 73.92 % | 5/7 |
| MANCHESTER - 100% | MANCHESTER - 100% | GATEWAY - 100 % | SUCPER | 100 - 73.92 % | 5/7 |
| GATEWAY - 100% | GATEWAY - 100% | THREE RIVERS - 100% | SUCGRD | 100 - 73.92 % | 6/6 |
| THREE RIVERS - 95.23% | THREE RIVERS – 95.23% | NORTHWESTERN – 100% | | | |
| NORTHWESTERN – 91.38% | NORTHWESTERN – 91.38% | TUNXIS - 100% | | | |
| TUNXIS - 90.01% | TUNXIS - 90.01% | NORWALK - 98.73% | | | |
| NORWALK - 86.12% | NORWALK - 86.12% | NAUGATUCK - 75.39% | | | |
| NAUGATUCK - 73.92% | NAUGATUCK - 73.92% | | | | |

## Table 4.13 Efficiency Scores Sensitivity as per Unit Elimination

| Unit | Score,% |
|---|---|
| Middlesex | 100.00 |
| Northwestern | 100.00 |
| Quinebaug Valley | 100.00 |
| Housatonic | 100.00 |
| Manchester | 100.00 |
| Capital | 100.00 |
| Three Rivers | 100.00 |
| Tunxis | 100.00 |
| Gateway | 100.00 |
| Norwalk | 98.73 |
| Naugatuck Valley | 75.39 |

As Asnuntuck was omitted from the group of colleges of the system, the above results showed that nine colleges had relative efficiency rating of 100%, Norwalk and Naugatuck obtained higher level of efficiency but remained below 100 % . The benchmark for Norwalk was Housatonic and Quinebaug , while Naugatuck had Capital, Housatonic, Manchester and Quinebaug to emulate.

This showed that the model was affected by the number of units that were present. This was expected, since this model yielded a relative efficiency, that is, one that depended on the performance of the peer units in the model.

**Table 4.14 Efficiency Scores Sensitivity as per model variables**

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCPER | SUCGRD | UNCH |
|---|---|---|---|---|---|---|---|---|
| RANGE % | 100-64.97 | 100-71.50 | 100- 62.06 | 100-62.06 | 100-73.92 | 100-73.92 | 100-73.92 | 100-73.92 |
| No. of EFF. | 6 | 7 | 3 | 5 | 5 | 5 | 6 | 7 |
| No. of INEFF. | 6 | 5 | 9 | 7 | 7 | 7 | 6 | 5 |

In the above table, each column with a specific variable represented the condition when the variable was removed from the study and the number of efficient and inefficient units resulted. Compared to the unchanged (UNCH) column, the model was least sensitive to the omission of the number of fulltime instructors (FTEINST) variable and most affected by the deletion of STUSERV variable. These were very important results that were used for development of further discussion on the model dependence on the variables.

**Table 4.15 Efficiency scores sensitivity as per variable values**

| Unit | Score |
|---|---|
| Asnuntuck | 100.00 0 |
| Quinebaug Valley | 100.00 0 |
| Middlesex | 100.00 0 |
| Housatonic | 100.00 0 |
| Manchester | 100.00 0 |
| Capital | 100.00 0 |
| Gateway | 100.00 0 |
| Three Rivers | 95.23 0 |
| Tunxis | 92.94 0 |
| Northwestern | 91.38 0 |
| Norwalk | 90.64 0 |
| Naugatuck Valley | 72.05 0 |

The model appeared to be least sensitive to the changes in its variable values. The efficiency scores shown above were obtained by removing the TGANG variable and the FTEINST variable for all the units of the study. These values were chosen quite arbitrarily or at random, as the statistician would say. The results of seven efficient colleges and five inefficient colleges were the same obtained when the model was run undisturbed. However, the inefficient units received a lower efficiency rating as compared to the values they had received on the initial runs of the model.

## Sensitivity of the study results using a different DEA Model

The sensitivity of the Frontier Analysis Model, which was developed by Banxia Software Ltd., was measured by comparing its results to those of a different DEA model that was published by Cooper, Seiford and Tone, using the same data set.

### Table 4.16 SUMMARY of DEA Model Results

Workbook Name = A:\Dissertation DEA
Results.xls
Data File = C:\Dissertation\DEA MODEL INPUT.xlsSheet1
DEA model = CCR-O
Problem = COLLEGES

No. of DMUs = 12
No. Input items = 3
Input(1) = TSCHRS
Input(2) = FTEINST
Input(3) = STUSERV
No. of Output items = 4
Output(1) = TOTREV
Output(2) = TGANG
Output(3) = SUCGRDS
Output(4) = SUCPER

Returns to Scale = Constant (0 =< Sum of Lambda < Infinity)

Statistics on Input/Output Data

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCGRDS | SUCPER |
|---|---|---|---|---|---|---|---|
| Max | 11.2 | 129 | 6.46 | 33.01 | 577 | 19.53 | 80.5 |
| Min | 2.1 | 21 | 1.34 | 8.52 | 127 | 4.49 | 38.93 |
| Average | 5.491666 | 68.83333 | 2.72 | 19.51 | 326 | 11.77416 | 71.45333 |
| SD | 2.643374 | 36.12901 | 1.452130 | 7.881160 | 134.7837 | 5.046446 | 10.01903 |

Correlation

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCGRDS | SUCPER |
|---|---|---|---|---|---|---|---|
| TSCHRS | 1 | 0.965492 | 0.788084 | 0.966477 | 0.882091 | 0.879785 | -0.005071 |
| FTEINST | 0.965492 | 1 | 0.838034 | 0.980551 | 0.872931 | 0.909903 | -0.047446 |
| STUSERV | 0.788084 | 0.838034 | 1 | 0.822288 | 0.627121 | 0.768878 | 0.120942 |
| TOTREV | 0.966477 | 0.980551 | 0.822288 | 1 | 0.847376 | 0.894743 | -0.138297 |
| TGANG | 0.882091 | 0.872931 | 0.627121 | 0.847376 | 1 | 0.863736 | 0.016498 |
| SUCGRDS | 0.879785 | 0.909903 | 0.768878 | 0.894743 | 0.863736 | 1 | 0.203113 |
| SUCPER | -0.005071 | -0.047446 | 0.120942 | -0.138297 | 0.016498 | 0.203113 | 1 |
| | | | | | | | |

DMUs with inappropriate Data with respect to the chosen Model

| No. | DMU |
|---|---|
| | None |

| | |
|---|---|
| No. of DMUs | 12 |
| Average | 0.953321 |
| SD | 0.073879 |
| Maximum | 1 |
| Minimum | 0.739196 |

Frequency in Reference Set

| Peer set | Frequency to other DMUs |
|---|---|
| Asnuntuck | 5 |
| Capital | 4 |
| Gateway | 0 |
| Housatonic | 2 |
| Manchester | 2 |
| Middlesex | 0 |
| Quinebaug | 0 |

| | |
|---|---|
| No. of DMUs in Data = | 12 |
| No. of DMUs with inappropriate Data = | 0 |
| No. of evaluated DMUs = | 12 |

| | |
|---|---|
| Average of scores = | 0.953321 |
| No. of efficient DMUs = | 7 |
| No. of inefficient DMUs = | 5 |
| No. of over iteration DMUs = | 0 |

[CCR-O] LP started at 03-04-2002 15:32:31 and completed at 03-04-2002 15:32:40

Elapsed time = 10 seconds
Total number of simplex iterations = 76

## REFERENCE SET

Model Name = CCR-O
Workbook Name = A:\Dissertation DEA Results.xls

| No. | DMU | Score | Rank | Reference set (lambda) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Asnuntuck | 1 | 1 | Asnuntuck | 1 | | | | |
| 2 | Capital | 1 | 1 | Capital | 1 | | | | |
| 3 | Gateway | 1 | 1 | Gateway | 1 | | | | |
| 4 | Housatonic | 1 | 1 | Housatonic | 1 | | | | |
| 5 | Manchester | 1 | 1 | Manchester | 1 | | | | |
| 6 | Middlesex | 1 | 1 | Middlesex | 1 | | | | |
| 7 | Naugatuck | 0.7391969 | 12 | Asnuntuck | 0.82171<br>1 | Capital | 0.827964 | Housaton<br>ic | 0.972784 |
| 8 | Northwest | 0.9138257 | 10 | Asnuntuck | 1.11463<br>4 | Capital | 7.24E-03 | Manchest<br>er | 1.21E-02 |
| 9 | Norwalk | 0.9064398 | 11 | Asnuntuck | 3.23601<br>8 | Capital | 0.154522 | | |
| 10 | Quinebaug | 1 | 1 | Quinebaug | 1 | | | | |
| 11 | Three Rivers | 0.9523083 | 8 | Asnuntuck | 1.21462<br>8 | Manche<br>ster | 0.422452 | | |
| 12 | Tunxis | 0.9280838 | 9 | Asnuntuck | 1.51610<br>3 | Capital | 0.189294 | Housaton<br>ic | 0.108410 |

In Rank order

| Rank | DMU | Score |
|---|---|---|
| 1 | Asnuntuck | 1 |
| 1 | Capital | 1 |
| 1 | Gateway | 1 |
| 1 | Housatonic | 1 |
| 1 | Manchester | 1 |
| 1 | Middlesex | 1 |
| 1 | Quinebaug | 1 |
| 8 | Three Rivers | 0.9523083 |
| 9 | Tunxis | 0.9280838 |
| 10 | Northwest | 0.9138257 |
| 11 | Norwalk | 0.9064398 |
| 12 | Naugatuck | 0.7391969 |

# PROJECTIONS

Model Name = CCR-O
Workbook Name = A:\Dissertation DEA Results.xls

| No. | DMU I/O | Score Data | Projection | Difference | % |
|---|---|---|---|---|---|
| 1 | Asnuntuck | 1 | | | |
| | TSCHRS | 2.3 | 2.3 | 0 | 0.00% |
| | FTEINST | 22 | 22 | 0 | 0.00% |
| | STUSERV | 1.58 | 1.58 | 0 | 0.00% |
| | TOTREV | 9.52 | 9.52 | 0 | 0.00% |
| | TGANG | 197 | 197 | 0 | 0.00% |
| | SUCGRDS | 6.3 | 6.3 | 0 | 0.00% |
| | SUCPER | 80.5 | 80.5 | 0 | 0.00% |
| 2 | Capital | 1 | | | |
| | TSCHRS | 4.9 | 4.9 | 0 | 0.00% |
| | FTEINST | 67 | 67 | 0 | 0.00% |
| | STUSERV | 1.9 | 1.9 | 0 | 0.00% |
| | TOTREV | 21.6 | 21.6 | 0 | 0.00% |
| | TGANG | 292 | 292 | 0 | 0.00% |
| | SUCGRDS | 7.5 | 7.5 | 0 | 0.00% |
| | SUCPER | 38.93 | 38.93 | 0 | 0.00% |
| 3 | Gateway | 1 | | | |
| | TSCHRS | 6.2 | 6.2 | 0 | 0.00% |
| | FTEINST | 95 | 95 | 0 | 0.00% |
| | STUSERV | 2.53 | 2.53 | 0 | 0.00% |
| | TOTREV | 22.82 | 22.82 | 0 | 0.00% |
| | TGANG | 393 | 393 | 0 | 0.00% |
| | SUCGRDS | 15.62 | 15.62 | 0 | 0.00% |
| | SUCPER | 76.2 | 76.2 | 0 | 0.00% |
| 4 | Housatonic | 1 | | | |
| | TSCHRS | 5.4 | 5.4 | 0 | 0.00% |
| | FTEINST | 57 | 57 | 0 | 0.00% |
| | STUSERV | 1.89 | 1.89 | 0 | 0.00% |
| | TOTREV | 19.48 | 19.48 | 0 | 0.00% |
| | TGANG | 286 | 286 | 0 | 0.00% |
| | SUCGRDS | 14.39 | 14.39 | 0 | 0.00% |
| | SUCPER | 74.24 | 74.24 | 0 | 0.00% |
| 5 | Manchester | 1 | | | |
| | TSCHRS | 8.3 | 8.3 | 0 | 0.00% |
| | FTEINST | 106 | 106 | 0 | 0.00% |
| | STUSERV | 2.89 | 2.89 | 0 | 0.00% |
| | TOTREV | 27.03 | 27.03 | 0 | 0.00% |

| | | | | | |
|---|---|---|---|---|---|
| | TGANG | 577 | 577 | 0 | 0.00% |
| | SUCGRDS | 18.77 | 18.77 | 0 | 0.00% |
| | SUCPER | 73.32 | 73.32 | 0 | 0.00% |
| | | | | | |
| 6 | Middlesex | 1 | | | |
| | TSCHRS | 3.3 | 3.3 | 0 | 0.00% |
| | FTEINST | 38 | 38 | 0 | 0.00% |
| | STUSERV | 1.43 | 1.43 | 0 | 0.00% |
| | TOTREV | 12.31 | 12.31 | 0 | 0.00% |
| | TGANG | 155 | 155 | 0 | 0.00% |
| | SUCGRDS | 7.41 | 7.41 | 0 | 0.00% |
| | SUCPER | 72.96 | 72.96 | 0 | 0.00% |
| 7 | Naugatuck | 0.7391969 | | | |
| | TSCHRS | 11.2 | 11.2 | 0 | 0.00% |
| | FTEINST | 129 | 129 | 0 | 0.00% |
| | STUSERV | 4.71 | 4.71 | 0 | 0.00% |
| | TOTREV | 33.01 | 44.65657 | 11.64657 | 35.28% |
| | TGANG | 487 | 681.8592 | 194.8592 | 40.01% |
| | SUCGRDS | 16.48 | 25.38488 | 8.904889 | 54.03% |
| | SUCPER | 73.1 | 170.5999 | 97.49998 | 133.38% |
| 8 | Northwest | 0.9138257 | | | |
| | TSCHRS | 2.7 | 2.7 | 0 | 0.00% |
| | FTEINST | 33 | 26.29520 | -6.704794 | -20.32% |
| | STUSERV | 1.81 | 1.81 | 0 | 0.00% |
| | TOTREV | 10.14 | 11.09620 | 0.956207 | 9.43% |
| | TGANG | 209 | 228.7088 | 19.70880 | 9.43% |
| | SUCGRDS | 6.21 | 7.304582 | 1.094582 | 17.63% |
| | SUCPER | 72.95 | 90.90095 | 17.95095 | 24.61% |
| 9 | Norwalk | 0.9064398 | | | |
| | TSCHRS | 8.2 | 8.2 | 0 | 0.00% |
| | FTEINST | 123 | 81.54537 | -41.45462 | -33.70% |
| | STUSERV | 6.46 | 5.406500 | -1.053499 | -16.31% |
| | TOTREV | 30.95 | 34.14456 | 3.194569 | 10.32% |
| | TGANG | 394 | 682.6160 | 288.6160 | 73.25% |
| | SUCGRDS | 19.53 | 21.54583 | 2.015830 | 10.32% |
| | SUCPER | 74.23 | 266.5150 | 192.2850 | 259.04% |
| 10 | Quinebaug | 1 | | | |
| | TSCHRS | 2.1 | 2.1 | 0 | 0.00% |
| | FTEINST | 21 | 21 | 0 | 0.00% |
| | STUSERV | 1.34 | 1.34 | 0 | 0.00% |
| | TOTREV | 8.52 | 8.52 | 0 | 0.00% |
| | TGANG | 127 | 127 | 0 | 0.00% |
| | SUCGRDS | 4.49 | 4.49 | 0 | 0.00% |
| | SUCPER | 74.24 | 74.24 | 0 | 0.00% |
| 11 | Three Rivers | 0.9523083 | | | |
| | TSCHRS | 6.3 | 6.3 | 0 | 0.00% |
| | FTEINST | 77 | 71.50177 | -5.498221 | -7.14% |
| | STUSERV | 3.14 | 3.14 | 0 | 0.00% |

| | | | | | |
|---|---|---|---|---|---|
| | TOTREV | 19.59 | 22.98214 | 3.392149 | 17.32% |
| | TGANG | 460 | 483.0368 | 23.03680 | 5.01% |
| | SUCGRDS | 12.96 | 15.58158 | 2.621589 | 20.23% |
| | SUCPER | 72.67 | 128.7517 | 56.08177 | 77.17% |
| 12 | Tunxis | 0.9280838 | | | |
| | TSCHRS | 5 | 5 | 0 | 0.00% |
| | FTEINST | 58 | 52.21642 | -5.783573 | -9.97% |
| | STUSERV | 2.96 | 2.96 | 0 | 0.00% |
| | TOTREV | 19.15 | 20.63391 | 1.483910 | 7.75% |
| | TGANG | 335 | 384.9519 | 49.95192 | 14.91% |
| | SUCGRDS | 11.63 | 12.53119 | 0.901194 | 7.75% |
| | SUCPER | 74.1 | 137.4640 | 63.36401 | 85.51% |

## WEIGHTS

lel Name = CCR-O
kbook Name = A:\Dissertation DEA Results.xls

| No. | DMU | Score | | V(1) | V(2) | V(3) | | U(1) | U(2) | U(3) | U( |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Asnuntuck | 1 | | 0.368985 | 6.88E-03 | 0 | | 0.105042 | 0 | 0 | |
| 2 | Capital | 1 | | 0.204081 | 0 | 0 | | 4.63E-02 | 0 | 0 | |
| 3 | Gateway | 1 | | 0.115813 | 0 | 0.111445 | | 1.98E-02 | 8.54E-04 | 1.36E-02 | |
| 4 | Housatonic | 1 | | 2.03E-02 | 1.18E-02 | 0.115640 | | 5.13E-02 | 0 | 0 | |
| 5 | Manchester | 1 | | 9.32E-02 | 0 | 7.83E-02 | | 0 | 7.37E-04 | 3.06E-02 | |
| 6 | Middlesex | 1 | | 0.192498 | 0 | 0.255072 | | 5.54E-02 | 0 | 0.017335 | 2.60E-0 |
| 7 | Naugatuck | 0.7391969 | | 1.20E-02 | 6.95E-03 | 6.82E-02 | | 3.03E-02 | 0 | 0 | |
| 8 | Northwest | 0.9138257 | | 0.245656 | 0 | 0.238137 | | 3.49E-02 | 3.09E-03 | 0 | |
| 9 | Norwalk | 0.9064398 | | 0.134538 | 0 | 0 | | 2.83E-02 | 0 | 6.31E-03 | |
| 10 | Quinebaug | 1 | | 0 | 2.43E-02 | 0.365235 | | 9.82E-02 | 0 | 0 | 2.20E-0 |
| 11 | Three Rivers | 0.9523083 | | 0.115075 | 0 | 0.103535 | | 0 | 2.17E-03 | 0 | |
| 12 | Tunxis | 0.9280838 | | 0.177329 | 0 | 6.45E-02 | | 3.75E-02 | 0 | 2.43E-02 | |

## Virtual Inputs/Virtual Outputs

el Name = CCR-O
kbook Name = A:\Dissertation DEA
ılts.xls

| No. | DMU | Score | | VX(1) | VX(2) | VX(3) | UY(1) | UY(2) | UY(3) | UY( |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Asnuntuck | 1 | | 0.848666 | 0.151333 | 0 | 1 | 0 | 0 | |
| 2 | Capital | 1 | | 1 | 0 | 0 | 1 | 0 | 0 | |
| 3 | Gateway | 1 | | 0.718042 | 0 | 0.281957 | 0.452164 | 0.335538 | 0.212297 | |
| 4 | Housatonic | 1 | | 0.109769 | 0.671670 | 0.218559 | 1 | 0 | 0 | |
| 5 | Manchester | 1 | | 0.773771 | 0 | 0.226228 | 0 | 0.425425 | 0.574574 | |
| 6 | Middlesex | 1 | | 0.635245 | 0 | 0.364754 | 0.682035 | 0 | 0.128456 | 0.1895 |
| 7 | Naugatuck | 0.7391969 | | 0.134353 | 0.897046 | 0.321419 | 1 | 0 | 0 | |
| 8 | Northwest | 0.9138257 | | 0.663271 | 0 | 0.431028 | 0.353383 | 0.646616 | 0 | |
| 9 | Norwalk | 0.9064398 | | 1.103217 | 0 | 0 | 0.876828 | 0 | 0.123171 | |
| 10 | Quinebaug | 1 | | 0 | 0.510584 | 0.489415 | 0.836582 | 0 | 0 | 0.1634 |
| 11 | Three Rivers | 0.9523083 | | 0.724977 | 0 | 0.325102 | 0 | 1 | 0 | |
| 12 | Tunxis | 0.9280838 | | 0.886647 | 0 | 0.190841 | 0.717374 | 0 | 0.282625 | |

## SLACKS

el Name = CCR-O

kbook Name = A:\Dissertation DEA
ılts.xls

| No. | DMU | Score | Excess TSCHRS S-( 1) | Excess FTEINST S-( 2) | Excess STUSERV S-( 3) | Shortage TOTREV S+( 1) | Shortage TGANG S+( 2) | Shortage SUCGRDS S+( 3) | Shortag SUCPE S+( |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Asnuntuck | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 2 | Capital | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 3 | Gateway | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 4 | Housatonic | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 5 | Manchester | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 6 | Middlesex | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 7 | Naugatuck | 0.7391969 | 0 | 0 | 0 | 0 | 23.03613 | 3.090423 | 71.7088 |
| 8 | Northwest | 0.9138257 | 0 | 6.704794 | 0 | 0 | 0 | 0.508976 | 11.0717 |
| 9 | Norwalk | 0.9064398 | 0 | 41.45462 | 1.053499 | 0 | 247.9484 | 0 | 184.623 |
| 10 | Quinebaug | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 11 | Three Rivers | 0.9523083 | 0 | 5.498221 | 0 | 2.411082 | 0 | 1.972552 | 52.4424 |
| 12 | Tunxis | 0.9280838 | 0 | 5.783573 | 0 | 0 | 23.99317 | 0 | 57.6220 |

In summary of this section on Sensitivity Analysis, the model showed a level of applicative robustness when changes were made to the variable values, using a different DEA coding and to a lesser extent when an entire variable was removed from the data set. The model results were least affected when the FTEINST variable was removed from the input data as compared to the removal of the other variables of the study. However, upon the removal of the unit with the highest frequency in the Reference Set, the model results were most affected. Three more units attained the 100 % efficiency rating. This was expected, since this study developed a relative efficiency rating based on the performance of each unit. Mention should be made of the fact that the term "Applicative

Robustness" was used and not Robustness, because the determination of a robustness factor should be based on the DEA system and the mode of solution of the Mathematical Linear Programming problems coupled with marginal increases in stability variables of the matrices involved. This in my opinion was too theoretical and not germane to the intent to the study. Hence, the Robustness was based on the changes observed in the efficiency values as data and system code changes were made.

# Chapter 5

# Summary and Conclusions

## 5.1 Summary

The inherent concern of institutions of higher education to acquire adequate resources waxes and wanes, but never goes away. In the United States and so Connecticut, the 1960s were times when growth justified considerable support for buildings, faculty, scholarship, and overall positive attitudes by the general public. In most other times, support has increased or decreased with the public's expectations of the common good of higher education. Generally speaking, a college degree has not always ensured a good job or a secured future for all graduates and as a result, society is questioning whether a higher education warrants additional taxes to support increased funding requests when compared to competing interests and needs. Today, the public has higher education under heavy scrutiny and is clamoring for higher levels of efficiency and accountability without weakening access and quality of the education experience.

On the other hand, The Community College Fact Book stated that community colleges represent a financially efficient segment of Higher education, educating 43 percent of the US undergraduate for a disproportionately small share of state and federal higher education monies (El-Khawas, Carter, and Ottinger 1988,xviii). Although a majority of all entering freshmen begin their collegiate studies at community colleges and state funds account for 50 percent of community college revenues, two-year colleges receive only 19 percent of state funds for higher education and less than 10 percent of federal higher education funds. Community college spokespersons must begin to make a more persuasive case for more adequate funding.

In Connecticut within the growing Community College System, the colleges are responding to the cost containment by reducing expenditures (for example, more low enrollment classes are constantly being removed, etc.) and seeking new sources of revenue (more grant proposal are being written).

With the adoption of effective strategies during financial stress, many colleges are learning how to manage effectively. The resulting issue then would be the task of sustaining adaptations to changes in the external environment while protecting excellence in the mission of discovery, dissemination and preservation of knowledge. A college may be considered an enterprise in which the professional staff and faculty provide the operating conditions for transforming quantifiable resources (inputs) into graduates (outputs). As explained by Bessent et al. 1982, school administrators can increase the productivity of individual schools through the hiring and assignment of personnel and through the provision of resources and incentives that have the potential for increasing production if they are efficiently employed.

The aim of this study was to develop guidelines for improving the overall performance (efficiency) of the Community Colleges of Connecticut using a linear programming technique called Data Envelopment Analysis (DEA). . DEA has evolved from the Simplex Method of Mathematical Linear Programming into a comprehensive computer assisted mathematical model for performing comparison between units with wide ranges of inputs and various outputs. No other method provided an overall operational definition – either conceptually or implementationally – of the efficiency of a school ( Bessent et al., 1982).

This new DEA method was developed to determine the relative efficiency of subunits of a system where the production functions between the inputs and the outputs of the subunits were unknown. DEA was very much suited for the analysis of institutions of higher learning within a higher education system as that of the Community Colleges System of Connecticut, primarily because the functional relationship between resources and outputs was not available and very difficult to obtain, and the model had the facility of handling multiple inputs and multiple outputs without priori definition of the weighting of the input/output variables.

From the analysis of the twelve community colleges in the Community College System of Connecticut, the model deemed seven colleges to be operating at 100% efficiency and five colleges to be operating below the 100% level. These results were nicely corroborated by a second DEA model developed by Cooper et al (2000) and also paralleled by the findings of a senior financial administrator at one of the member college.

The study showed a distinctive trend in the operation of the five inefficient units: most of the units in this group over consumed the resources and under produced the outputs by their respective percentages as determined by the model and shown in their individual analysis in Chapter 4 of this study.

The number of units (twelve) used in this study was too small for the minimal number of three inputs and four outputs in order that the DEA model would meet Degree of Freedom constraints. This was determined by the rule of thumb that was outlined elsewhere in the study. Hence, the results of the model did yield a relatively higher number of efficient units. When the number of variables (7) , that were originally used in this study was reduced to meet the guidelines of the rule of thumb, this resulted in a sizeable decrease in the number of efficient units in the system. With two inputs and two outputs, which represented a massive decrease in the aspects of the colleges' performance, the model showed that there were only two units that were operating efficiently.

## 5.2 Conclusion

The results of this study indicated that DEA showed great promise as a tool for evaluating the efficiency of Institutions of Higher Learning among many organizations. This method's ability to take into account the multiple outputs and multiple inputs was used to provide perspective on other managerial accounting tools similar to the Cost-per-unit type of analysis, and had proven to be superior to these productivity factors types of tools. As described by Ahn, Charnes and Cooper (1988), DEA can also be used as an alternative and perhaps more easily used approach than was provided by statistical regressions and similar techniques, like the index number construction method where a variety of a priori assumptions and /or weighting techniques must be provided for the analysis. This was inadequate for the determinations needed to be made in this study. DEA invariance to units and many other flexibilities made it very suitable for this study and attractive to many researchers, however, as was demonstrated in the study, the model had a serious handicap that concerned the number of units analyzed and the number of input/output variables that could be actually used to characterize a unit in the study.

The small sample of units (twelve) is really stretching the DEA process beyond its capabilities, and since this number of units of the system cannot be changed, coupled with the complexity of the performance of the colleges one is encouraged to apply the results of the model cautiously with the suitable hesitation and caveats about the conclusion. The greater the number of variables that are included, a better characterization of the colleges' performance is taken into account, however, this would yield a greater number of colleges on the 100% efficiency frontier. Hence there is a tension between validity of the modeling ( the number of variables used to characterize the colleges) and the discrimatory power ( the number of efficient units yielded) of the DEA Model. As shown in chapter 4 above when the number of variables is decreased, merely to stay within the rule of thumb, there was a drastic decrease in the number of efficient units

## Strengths and Weaknesses of the DEA Procedure

A. The DEA is a multi-input and multi-output linear programming based system used to calculate the relative efficiency of organizations, agencies, and public or private not-for-profit institutions of higher education called decision Making Units (DMU's).

B. DEA permitted each DMU to select any weights it wanted to use for each input and output. As per the classical definition of efficiency, DEA used a ratio of a sum of weighted outputs to a sum of weighted inputs. Hence it does not require the user to supply weights to be attached to each input and output.

C. DEA does not require prior description of any functional relationship that existed between the inputs and the outputs of the model.

D. The DMU's of a DEA system are compared to the best performer of the group, so the relative efficiency of each DMU is calculated using the best performer as reference, as opposed to the Regression Method where each unit is compared to an average performance of all the units.

E. As per the rule of thumb concerning the number of units analyzed by DEA, outlined elsewhere in the study, the model was very sensitive to the number of units analyzed and the number of input and output variables used to characterize the unit.

F. DEA identified the resources and the amounts of deficiencies of specific resources that were responsible for the low level of performance of a given unit.

G. Because DEA Efficiency Scores are related they cannot be used as factors in Regression Analysis to determine any other statistics of the scores. A Bootstrap Procedure must be performed.

There were other shortcomings and strengths of the DEA that would be best demonstrated by using examples. Consider the manager of an inefficient DMU who used DEA results to identify inputs that were in excess of the amount needed if the unit was to be efficient. This valuable information was used to indicate unproductive processes internal to the unit. Similarly, the manager or administrator might be required to justify some input that he or she has in oversupply and for which a more effective use was prevented by constraints over which he or she had no control.

The administrator of a set off DMU's (say colleges) had additional problems concerning the input allocations to subunits, and the DEA was less informative at this level. The administrator aim was to allocate available resources to individual units in a manner that will maximize the overall outputs of all subunits in some usefully defined way. In this way, DEA can be used to provide pointers, but something more concrete was needed in the way of overall planning models to achieve the overall "best" allocations. Here too, DEA could help in supplying the needed coefficient values that were derivable from the values of the virtual multipliers obtained from the DEA application, as discussed in previous sections of this study.

In the case of efficient units there was the question: Will additional input enable unit administrators to increase output? If so, which inputs were the most promising for additional allocation? Suppose the administrator knew or made a guess – based on knowledge of the technology area and assisted by the DEA results – where to reallocate inputs. There was then the question: How much should be allocated to and withdrawn from which units to optimize overall output of the units under his or her charge? A value structure or some sort of judgment must enter when these choices were to be made. However, as per Bessent,1983, many conditions limit what can be done, the fact that many faculty members were tenured and specialized and many programs required expensive, high technology equipment reduced the flexibility for reassignment of faculty and space. Equipment could be removed, new equipment could be installed, and faculty could be retrained but this would require additional time that were not considered in the problem.

As outlined in the previous chapter of this study, the analysis of the DEA results followed the three research questions of the study.

Research Question # 1

How do institutions of the Community College System of Connecticut compare to each other regarding their levels of efficiency?

DEA was applied to a sample of the 12 colleges, the model produced an empirically based measure of each college's ability to produce desired outputs from the inputs. The analysis showed that seven colleges were ranked efficient and the remaining five had a performance assessment below 100 % efficiency rating. Quinebaug Valley, Asnuntuck, Middlesex, Capital, Housatonic, Manchester, and Gateway Community Colleges comprised the group that attained 100 % performance efficiency rating. While Three Rivers, Northwestern, Tunxis, Norwalk and Naugatuck Valley Community Colleges had efficiency rating ranging from 95.23 % to 73.92 %. It should be reiterated that these results were based on the three inputs namely: TSCHRS – total student contact hours generated by each college - (which acted as a surrogate for five other inputs with which it was highly correlated), FTEINST – the number of Full Time Equivalent Instructors and STUSERV – Student Services Expenditure and four outputs TOTREV – Total Revenue, TGANG – total number of students completing degrees and certificate programs, SUCGRDS – Total credit awarding grades given by the faculty., and SUCPER – percentage of successful grades awarded. Within the group represented by TSCHRS there were some very strong variables which had great descriptive potentials but had to be included in a group because of the high level of correlation that existed within that group and the constraint of the number of variables that could have been possibly used in the study. I strongly believe that each college performed well for the different environmental conditions which they served for the period 1999-2000. There were many non-tangible factors, excluded from the study, that were also responsible for the differences in their efficiency level of performance of the various units. It should be recognized that in this study only the technical efficiency, that is, efficiency based on the organization of the available resources in such a way that the maximum feasible output is produced, was addressed.

## Research Question #2

What conditions may account for the differences in the level of success within similarly efficient colleges?

This model did not show any potential improvement of a unit once it was placed on the frontier efficiency line, that is, given the efficiency rating of 100 %. Hence, to draw conclusion on the differences between the efficient units (colleges), direct comparison of the values of the input and output variables had to be made. For instance, Manchester Community College had the highest

OEAS, expenditure for Administration and Academic Services, although the college did not have the highest student population for the period of the study, 1999-2000.in the System. There were many more conclusions that could have been drawn by the mere examination of the data values which were included in Table 4.3.

Research Question #3

What factors or constraints create the varying scores among inefficient colleges?

The seven variables of this study were identified as factors contributing at varying levels of efficiency of the inefficient units analyzed in this research. All of the resources of these units were over consumed and most of the products were under produced. From the research, this was the most typical scenario in the analysis of educational systems. In this study there were five colleges that were rated below 100 % efficiency, as shown in table 4.4, the inputs of all the inefficient units were over consumed and had potential improvements in the form of a reductions of the resources used, and all the outputs, with the exceptions of the TOTREV and TGANG variables had to be increased, for each of the units in this category in order to achieve 100 % efficiency.
However, it should be noted that the DEA procedure did not yield absolute measures of efficiency, rather, the inefficient colleges were compared to an identified peer set (reference set) of colleges that were similar in their levels and mixes of inputs. Administrators of the colleges should measure

the performance of their individual college as compared to a norm. As pointed out by Bessent et al.,(1982), if an efficient school succeeds in raising its achievement more than others , then some schools that were formerly efficient may become inefficient and some inefficient schools may be reduced to even greater inefficiency.

The strength of the DEA lies in its ability to identify both sources and amounts of deficiencies for specific resources that were responsible for the low level of performance of a given unit. Colleges, which were identified as being relatively efficient, while having high levels of outputs, could have been studied by the less efficient colleges to identify the practices that were used by these successful colleges. College that were using their resources inefficiently and yet were achieving relatively high levels of outputs could have been examined to determine whether their resources should be reallocated to needier colleges. The important point to be made was that DEA results must be carefully examined to take full advantage of the diagnostic data that was available for each college's unique conditions. Decisions of the reallocation of resources (which also required further inquiry beyond DEA) must be made in the context of careful consideration of consequences for each member college within the system.

Although the model of this study presented a very quantitative outlook at the potential improvements that the Community Colleges could undertake to achieve higher levels of performance, there were limitations on the applications of this Linear Programming model to determine good results on the mere twelve colleges of the Connecticut System. As shown by the rough rule of thumb showed in the previous chapter:

$N \geq \max \{ m \times s, 3(m + s)\}$ where N is the number of units to be analyzed and m is the number of inputs and s the outputs

The System had 12 for the value of N, 3 for m and 4 for s, and so, as required by the rule of thumb, N must be greater than or equal to a maximum value between 3 x 4 and 3( 3 + 4 ), that is between 12 and 21. The N value of the study was in the vicinity of the interval, mandated by the rough rule of thumb, and so, the model was not as discriminating as it would have been with a larger number of colleges within the system. From the research it was evident that DEA had been widely used in various methods of performance assessment in a large genre of organizations, however, primarily because of the low number of units that were analyzed in the study, there appeared to be a relatively high number of efficient units.

## 5.3 Policy Recommendations and Implications

In general, it would seem to be unwise to give additional resources to inefficient units since that would only increase their inefficiency unless they could improve their technology by using the new resources.

The conclusions that were drawn from this study had implications for collaborative college improvements, for managerial techniques in college administration and for further research using the DEA procedure.

**Implications for collaborative efforts**

Implications concerning collaborative efforts for college improvements stemmed directly from the DEA results. The effective use of DEA results depend on shared strategies for college improvement, as well as upon shared sources of input and output data. Inherent in the results of the DEA model was the provision of a Reference Set for each inefficient unit. The Reference Set for each inefficient college, as demonstrated by the model and defined elsewhere in the study, should serve as the benchmark, with which the inefficient college should develop a collaboration. The reader is directed to Section 4.4 on Reference Set, where Northwest Community College (an inefficient unit) was provided the Reference Set of Asnuntuck, Capital and Manchester Community Colleges. The results of the study identified that the respective Reference Set had many commonalities with the inefficient unit, and so, some collaborative effort should be made to share resources within this group and to lift the identified inefficient college to an efficient level. Other collaborative work can be spearheaded within similar (those that were merged with a Technical College and the unmerged) colleges of the system. With the same idea of benchmarking provided by the Reference Set, the public four-year colleges can develop direct conversation with a selected community college for the sole purpose of developing collaborative efforts aimed at establishing better standards for the higher education process and sharing the limited resources appropriated by the State for Higher education.

**Implications for Managerial Techniques**

Operations managers (Deans and Administrators) at the colleges and the central governing bodies of the System could use DEA for providing quantitative proof of the funding needed to achieve goals and to improve overall performance of individual institution. DEA could also be used for the balancing of the appropriation of resources among the different colleges of the System. As a forecasting tool, programs can be evaluated with DEA, where the incremental changes in the inputs (resources) or the outputs (products) needed to achieve 100% efficient operation would be determined, thus, helping to produce successful outcomes. In essence, the DEA Procedure was likened to the quintessential " Weegie Board" where administrators could have: reallocated resources, identify the best practices, identify poor practices, set targets, monitor efficiency changes over time, award tokens for good performances and plan site for additional educational institution.

**Implications for further Research**

Implications for further research included the analysis of colleges and universities in a particular region; for example, the institutions of higher education within the New

England States appeared to have had considerable similarities but were still different. Hence, DEA could have had quite a number of applications in the determination of the factors that made these institutions perform differently.

As a second track for further research, the issue of resource allocation was once more considered. The administrators of inefficient units could use DEA to identify inputs that were in excess of the quantities required for the unit to be efficient. This is valuable data that might be used to identify the unproductive processes internal to the unit. As an alternative perspective, some administrator might be required to justify an input that he/she has in oversupply and for which a more effective use was forbidden by some politically motivated constraint. A similar issue arose for efficient units. Would additional input enable the unit manager to increase inputs on the efficient units? If so which inputs were the most promising for additional allocation. The question was best proposed by the statement ... How much should be allocated to and withdrawn from what units to optimize the overall output of the units under his/her charge....

Bessent (1983) alluded to a fact at San Antonio College which was very pertinent to this study of the Community College of Connecticut, the fact that many faculty were tenured and specialized and many programs required expensive, high technology equipment reduced the flexibility for reassignment of faculty and space. Equipment could be removed, new equipment installed and faculty could be retrained but that required extensions into dimensions of time that were not considered in the present analysis.

All of the above and more, in the form of some multiple objective modeling would be required in the same sense as the multiple input/ multiple output DEA evaluation that had been used in this study, should be considered for future research in DEA type analysis.

## 5.4 Closing Remarks

In closing, one can say that DEA showed great promise to be a good evaluative tool for future analysis on educational systems, where the production function between the inputs and outputs was virtually absent or extremely difficult to acquire. The facility of multiple inputs and multiple outputs of the DEA model was definitely an attractive one to most researchers and hence, the DEA procedure had found many applications beyond education into commerce, government and industry.

In the overall analysis, I believed that the Community Colleges of Connecticut performed well for their respective service area for the period 1999-2000. The discrimination created by the model whereby seven colleges were deemed efficient and five inefficient should act merely as an indicator for the need for further investigation of the operations at the respective colleges. The limited number of variables used to characterize the colleges, as demanded by the model for the small number of twelve colleges yielded results that would have been inherently better had the model been allowed to use more of the variables.

As outlined in the section on limitations of the DEA procedure, the DEA model had its shortcomings as any other mathematical modeling tool, and in my opinion, the study was severely handicapped by the small number of community colleges (12) in the system. The study was forced to use a mere three inputs and four outputs from the total of sixteen variables of data collected. There were many other important pieces of data that would have helped to further characterize the operations of the community colleges of this system, which had to be omitted from the calculations to attempt to meet the linear programming constraints of the DEA. This was very unfortunate, and although the number of units in the model criterion set by the rule of thumb, was not met, the results did depict a relatively accurate discrimination between the efficient and the inefficient units of the model, as observed by a senior financial administrator within the system of colleges.

The Community Colleges of Connecticut have come a long way, from their humble beginning of little more than a trade school to institutions of higher learning offering the first two years of the four-year baccalaureate programs, with learning environments that would rival that of a number of universities in the United States. However, although the Community Colleges had the autonomy to develop their individual programs and the ability to shape each college into whatever the chief administrators thought would be best for the service region, the quality markers that would place a college in the top 100 community colleges of the United States had never been achieved by any member college of the Community College System of Connecticut. The Appendix E of this study showed the list of the 100 top community colleges of the United States with their respective student population included. It should be noted that there were colleges in this top 100 group with student population lower than that of the community colleges of Connecticut for the period of the study, 1999-2000.

Hence, it was evident that the Community Colleges of Connecticut Central Office should adopt a quantitative approach, as demonstrated by the DEA model, to steer the various institutions to a higher level of performance, efficiency and accountability as demanded by the Legislature of the State of Connecticut. In doing so, missions, strategic plans and college developmental programs would have to be changed to transform the community colleges of Connecticut into a place of inquiry where dreams are no longer diverted and winners are made of ordinary people.

# Glossary

## Meaning of Terms

To facilitate a thorough understanding of this study, it is necessary to provide a glossary of the terms used in this research. The following is this list.

### INPUTS

A. **TSCHRS** - Student Contact Hours generated by each College (lecture and Lab. hours for one course per week times the number of students times the number of weeks of Instruction times the total number of courses offered in the academic year). This input is used in State Funding formulas and so it is audited to guarantee that only students enrolled in courses unique to a given program are counted. It represents an Input to the Output revenue generated and to number of completors. A student is considered a completor when this student has successfully completed coursework and has achieved stated educational goals.

B. **FTEINST** - The number of Full Time Equivalent (FTE) Instructors in each college. FTE should be based on a 12- credit-hour load for part-time staff members.

C. **TISQRF** - Facilities allocation as determined by the square feet assigned to each college for classroom, office, laboratory use and library facilities.

D. **TDIEXP** - Direct instructional expenditures in each college including salaries, equipment and instructional supplies.

E. **TOPP** - Total Operational Expenditure for Physical Plant ( building maintenance, grounds and custodial services)

F. **OEAS** - Overhead expenditure for Administrative and Academic support.

G. **STUSERV** – Expenditure for Student Services -- student club activities, trips, dances and some cafeteria expenses.

**OUTPUT**

A. **TOTREV** - Total revenue from Tuition, Fees, Government Appropriations and Credit Free programs. Revenue earned by contact hours through state funding formulas --- each college would lose revenue earned if the program were terminated.

B. **TGANG** - The number of students completing programs (Degrees and Certificates) or those who are far enough advanced to get a job. This output was chosen instead of the number of students enrolled because the latter is accounted for in the contact hour input and because the colleges have an announced goal of preparing for the available job market.

C. **EAS** - Employer/Admission satisfaction with training of students employed or transferred to a four-year institution.

D. **SUCGRDS** - Total credit awarding grades given by the faculty. This figure represents the courses for which the students received a passing grade (A to D- and P). This figure should include all matriculating and non-matriculating students. There are many students who come to the Community Colleges and do not receive a diploma, they merely took a few courses to sharpen their skills, change their careers or increase their knowledge base. This figure measures a level of deliverability of the college and so, should be included as an output for this study.

E. SUCPER - Percentage of successful grades awarded.

**Efficiency**: Efficiency relates to technical efficiency of a unit and refers to the utilization of resources in such a way to produce the maximum feasible output, that is, no other combination of resources could yield a larger output.

**Output:** Output is the measure of the results of a given system charged with the duty to utilize inputs.

**Input:** Input is defined as a resource or a factor of production that is used in a production process.

**Resource Allocation**: Resource Allocation is defined as the apportionment or utilization of personnel, material or funding to the colleges.

**Regression Analysis**: Regression Analysis is a statistical technique in which the degree to which a set of independent variables relate or form a relationship to a single dependent variable. The objective is to determine the best fit line that lies between data points using a least square principle. The method reflects an average or a central tendency behavior of the observation.

**Data Envelopment Analysis( DEA):** DEA is a calculation method derived from Mathematical Linear Programming and utilizes multiple inputs and outputs to determine the efficiency of the system from which the performance variables came. DEA deals with the best performance and evaluates all performances by deviation from a frontier line.

**Decision Making Unit (DMU):** The entity on which the analysis is being done, for example: a college, a bank or a transportation system.

**Slack Values:** Slack Values are the unnecessary consumption of resources or the shortcomings of output as determined by the DEA process.

**Return to Scale:** Return to scale represents the proportionate increase/decrease in outputs that results from a given increase/decrease in all inputs employed in the production process. Three possible relationships can exist between the change in inputs and the change in outputs:

For an increase in all inputs by a factor of K

1. Increasing return to scale : Output increases by more than K
2. Decreasing return to scale: output decreases by less than K
3. Constant return to scale : output increases by exactly K

## References

Ahn, T.S., Arnold, V., Charnes, A., Cooper, W.W. (1989), DEA and Ratio Efficiency Analyses for Public Institutions of Higher Learning in Texas, (Research in Government and Non-profit Accounting). Vol.5, 165-185.

Ahn, T.S. (1987), Efficiency and Related Issues in Higher Education: A Data Envelopment Analysis Approach. Ph.D. dissertation, Graduate School of Business, University of Texas. Source: Vol. 49 03-A of Dissertation Abstracts International. 543- 593

Aigner, D., Lovell, A. K. and Schmidt, P.(1977). *Formulation and estimation of stochastic frontier production function models*. (Journal of Econometrics), 6: 21-37

Athanassopoulos, A.D., and Shale, E. (1997), *Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis,: Education Economics* , vol. 5, no. 2,. 117-34,

Ball, R. and Wilkinson, R.H.(1992), *Measuring the Performance of Higher Education Institutions: The Application of Data Envelopment Analysis, Proceedings of the 13th International Forum of the European Association for Institutional Research* , M. Wright, ed., 219-234,

Banathy, B.A.(1991), *Examining Performance in Community Colleges: Data Envelopment Analysis as a Means of Increasing the Domain of Inquiry,* Ph.D.

dissertation, University of California. Source: Volume 52/08-A of Dissertation Abstracts International. 2761-2973

Banker, R.D. and Morey, R.C. (1986), *Efficiency Analysis for Exogenously Fixed Inputs and Outputs*, ( Operations Research 34), 513-521

Beasley, J.E.(1990), *Comparing University Departments, Omega-International* (Journal of Management Science) , vol. 18, no. 2,

Bessent, A.M. and Bessent, E.W.(1981), *Productivity in Community College Programs: A Technique for Determining Relative Efficiency*,( ed. D.T. Community Coll. Productivity Center)

Bessent, A..M. (1983), *Evaluation of educational program proposal by means of DEA*, (Educational Administration Quarterly), Vol. 19,No. 2, 82-107

Bessent, A.M. and Bessent, E.W, Charnes, Cooper, and Thorogood(1983), *Evaluation of Educational Programs Proposals by means of DEA*, (Educational Administration Quarterly),Vol. 3, No. 2, 82 – 107

Bhattacharyya A.,Lovell, C.A.K. and Shay,P., (1997), *The impact of Liberalization on the Productive Efficiency of Indian Commercial Banks'* (European Journal of Operation Research, 332-345.

.Charnes, A., Cooper, W.W., and Rhodes, E.L.(1981), *Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through*, (Management Science) ,vol. 27, no. 6, 668-697

.Charnes, A., Cooper, W.W., and Rhodes, E.L(1978), *Measuring the Efficiency of Decision Making Units*, European Journal of Operational Research, 2, 429 - 444

Charnes, W.W. , McLaren, C.H.(1994), Selection of Input and Output Measures in Data Envelopment Analysis of Large Indiana School Corporations, *Proceedings of the Annual Meeting- Decision Sciences Institute*, 2, pp.1215-1217,

Cooper, W.W, Lewin, A.Y, Seiford, L.M.(1994), Data Envelopment Analysis: Theory, Methodology, and Applications, 1994. (Kluwer Academic Publishers). Boston

Cooper, W.W., Seiford, L.M., Tone, K.( 2000), Data Envelopment Analysis, A Comprehensive Text with Models and Applications, ( Kluwer Academic Publishers), Boston/Dordrecht/London.

Cox, Mary Anne B.(2001), Summary and History of Connecticut Community Colleges, ( the System Office of the Connecticut Community Colleges)

Desai, A. (1986), Extension to Measures of Relative Efficiency with an Application to Educational Productivity, Ph.D. dissertation, University of Pennsylvania. Source: Volume 47/10-B Of Dissertation Abstracts International. 4285 - 4485.

Deprins, D. and Simar, L., (1989), Estimating Technical Efficiencies with Correction for Environmental Conditions with and Applications to Railways Companies, (Annals of Public and Cooperative Economics), 60, 1(Jan-Mar) 81-102.

El-Kawas, E., Carter, J.C. and Ottinger, Cecilia, A.(1988.) Community College Fact Book. (New York: MacMillian).

Farrell, M.J.(1957),*The measurement of Productive Efficiency* (Journal of Royal Statistical Society), 120,Sec. A, 253-281..

Ferrier, G.D. and Valdmanis, V., ( 1996), *Rural Hospital Performance and its correlates*, (Journal of Productivity, &, (1), 63-80)

Goldstein, Harvey.(1990), *Data Envelopment Analysis: An Exposition and Critique, Evaluation and Research in Education,* vol. 4, No.1.

Grosskopf S., (1996), *Statistical Inference and Non-Parametric Efficiency:A Selective Survey*, ( Journal of Productivity Analysis, 7, 161-176.

Haksever, C., and Muragishi, Y.(1998), *Measuring Value in MBA Programs*, (Education Economics), vol. 6,no. 1, 11-25,.

Hanke, M., and Leopoldseder, T.(1998), , 4/3, pp. 191-198, (Jessica Kingsley Publishers. London) *Comparing the Efficiency of Austrian Universities: A Data Envelopment Analysis Application, Tertiary Education and Management*

Harrison, M.E. Jr.(1988), *Measuring the Comparative Technical Efficiency of Universities , Ph.D. dissertation, Graduate School of Business Administration, University of North Carolina.* Vol. 50/03-A of Dissertation Abstracts International. Page 635. 418

Hauksson, A.G.(1988), *The Commercialization of University Research Discoveries: Are University Technology Transfer Offices Stimulating the Process?* Ph.D. dissertation, (Massachusetts Institute of Technology; 0753.)

Hussain and Brightman (2000), *Frontier Analyst- How Data Envelopment Analysis Works*, ( The Economic Journal)

Hoffman,A.J.(1957) Commentator to : *The Measure of productive Efficiency*,( Royal Statistical Society)

Justinger, M.E.S.(1986), *An Efficiency Analysis of Services for Adult Students at Community Colleges.* Ed. D. dissertation, State University of New York. Vol. 47/03-A of Dissertation Abstracts International. Page 767. 102

Jesson, David; Mayston, David; Smith, Peter,(1987), Performance Assessment in the Education Sector: educational and economic perspectives, (Oxford Review of Education), Vol. 13, No.3,

Johnes, Jill; Johnes Geraint (1995), Research Funding and Performance in U.K. University Departments of Economics: A Frontier Analysis, (Economics of Education Review), Vol.14,No.3 pp. 301-314

Johnson, S.L (1995), *Organizational Structure and the Performance of Contract Training Operations in American Community Colleges*, Ph.D. dissertation, (The University of Texas at Austin).

Kao, C.(1994), *Evaluation of Junior Colleges of Technology - The Taiwan Case*, (European Journal of Operational Research) , vol. 72, no. 1, 43-51.

Kwimbere, F.J.(1987), *Measuring Efficiency in Not-For-Profit Organizations: An Attempt to Evaluate Efficiency in Selected U.K. University Departments Using Data Envelopment Analysis (DEA)*. M.Sc. thesis, School of Management, University of Bath

Lovell, C.A.K.(1993), Production Frontiers and Production Efficiency, in Fried H.O., C.A.K. Lovell and SS Schmidt, eds., *The Measurement of Productive Efficiency: Techniques and Application* (Oxford University Press, UK).

Lovell, C.A.K.,Walters, L.C., and Wood, L.L.(1991), *Stratified Models of Education Production Using Modified DEA and Regression Analysis,*

Puttakul, W. (1994),*Technical Efficiency of Area Vocational-Technical Schools: An Illustrative Study of the Application of Data Envelopment Analysis (DEA)*. Ph.D. Dissertation, University of Missouri - Columbia;

Ray, S.C.(1991), *Resource-Use Efficiency in Public Schools: A Study of Connecticut Data,* (*Management Science),* vol. 37, no. 12, and pp. 1620-1628,

Reaves, L.J.(1983), *Using Data Envelopment Analysis to Operationalize the Concept of Equal Education Opportunity.* Ph.D. dissertation, College of Education, University of Texas. Vol. 44/04-A of Dissertation Abstracts International. Page 945 – 184.

Rhodes, E.L.(1978),*Data Envelopment Analysis and Approaches for Measuring the Efficiency of Decision-making Units with an Application to Program Follow-Through in U.S. Education.* Ph.D. dissertation,(School of Urban and Public Affairs, Carnegie-Mellon University). Vol. 41/08-A of Dissertation Abstracts International.

Seiford L.M., (1996), Data Envelopment Analysis: *The evolution of the State of the art( 1978-1995),* (Journal of Productivity Analysis, 7, 99-138.

Sexton, et al.,( 1986), *The methodology of Data Envelopment Analysis, in New Directions for program evaluation*, ( Jossey-Bass) Vol.32, No.2, Pg 7-29

Simar, L., Lovell, C.A.K., and Eeckaut, Vanden,P. (1994), *Stochastic Frontier Incorporating Exogenous Influences of Efficiency, Discussion paper 9403* (Institut de Statistique, Universite Catholique de Louvain, Belgium).

Simar, L. and Wilson (1995), *Sensitivity Analysis of Efficiency Sccores: How to Bootstrap in Non-parametric Frontier Models*, Discussion paper 9503 (Institut de Statistique Universite Catholique de Louuvain, Belgium)

Thorogood, N.J.C.(1983), *The Application and Utilization of Data Envelopment Analysis for Decision Support in the Administration of Instructional Programs for an Urban Community College.* Ph.D. dissertation, College of Education, University of Texas. Vol. 44/06-A of Dissertation Abstracts International. Page 1658. 252

Xue, M., and Harker, P.T.,(1999)*Overcoming the Inherent Dependency of DEA Efficiency Scores: A bootstrap Approach*, Working Papers 99-17, ( Financial Institution Center, The Wharton School, University of Pennsylvania).

# Appendix A

## How does Data Envelopment Analysis (DEA) work?

Data envelopment Analysis was developed to assist researchers and investigators evaluate and improve performance of their organizations. Managers were constantly under pressure to improve the performance and accountability of their respective organizations. It was a fact that in the public sector, government officials were seeking better value for taxpayers' money and on a larger scale, global economy had created competitive pressures on industrial and commercial companies.

Previously researchers and managers used factors like cost per unit or profit per unit to determine the productivity of a unit based on single variables, in this case cost or profit. This measure of productivity only yielded a partial productivity index for a given unit, and so, there would be need for many partial productivity indices to characterize a total productivity of any unit. The move from partial productivity index to total productivity index of any unit was met with many difficulties, such as the selection of the best inputs and outputs and the necessary weights needed for each of these variables to fit within a model. Also there was the life long problem of the production function that related the inputs to the outputs. However, the adoption of the DEA procedure eliminated the need for any of the above information and total productivity could be acquired for a unit.

As mentioned previously, the facility of using multiple inputs and multiple outputs without prior determination of production function that exists between the inputs and the outputs,

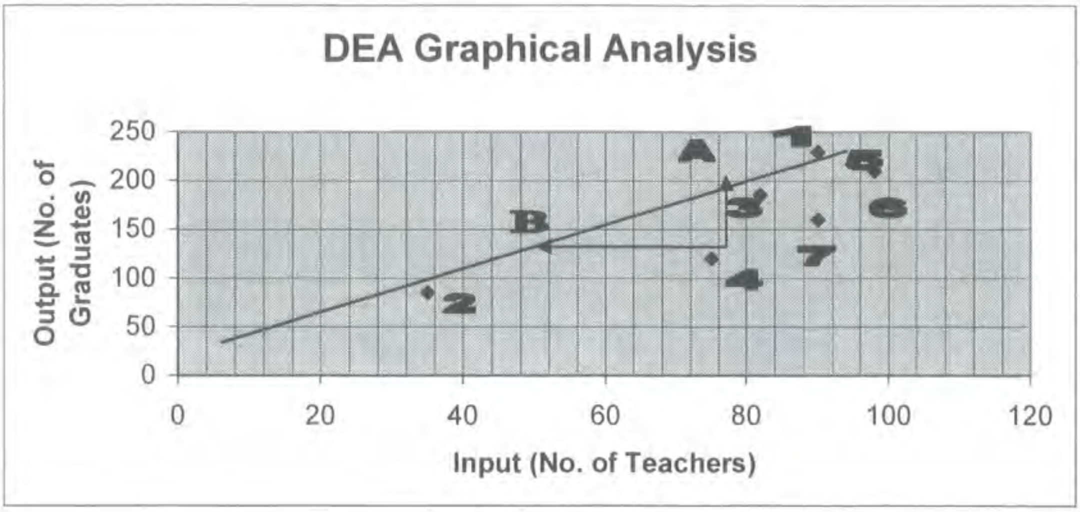
was the most attractive facet of the DEA procedure particularly in the determination of the efficiency of educational institutions. Apart from being able to discriminate between the efficient and the inefficient units, the DEA procedure had the ability to suggest potential improvement for specific variables of the inefficient units to bring them up to an efficient level of operation.

In order to graphically demonstrate the concept of Data Envelopment Analysis, two variables ( 1 inputs, the number of teachers and 1 outputs, number of graduates), with no known functional relationship between them, from seven high schools in the West Indies where a British type of education was used, were selected . At these schools a student graduated successfully only when he/she passed five subjects in the General Certificate of Education (GCE) examination at the end of a five-year period of high school studies.

The following data was obtained for the demonstration:

**Table A-1 High Schools Data**

| No. | School | Input<br>No. of teachers | Output<br>No. of Graduates | Productivity<br>Grad/teacher |
|---|---|---|---|---|
| 1 | St. Mary's | 90 | 230 | 2.55 |
| 2 | Holy Cross | 35 | 85 | 2.43 |
| 3 | Fatima | 82 | 185 | 2.25 |
| 4 | Trinity | 75 | 120 | 1.60 |
| 5 | Presentation | 95 | 218 | 2.29 |
| 6 | Queen's Royal | 98 | 210 | 2.14 |
| 7 | Senior Comp. | 90 | 160 | 1.77 |




The slope of the line drawn from the origin to any unit on the above graph determined the productivity (Graduates/ teacher) of each school and the highest slope, which was attained by the line that went through the origin and unit #1 was called the Efficient Frontier. This efficient frontier line envelopes the rest of the units, hence, the name Data Envelopment Analysis. The efficiency of the remaining units were measured up against the frontier line produced by unit # 1
(100% efficiency).

At this point, it was very important to highlight the deviation of the DEA procedure from the previously used statistical methods of analysis. Normally, to analyze the above data on the schools, one would develop a regression line through the data points and visually examine the units that fell above the regression line and were considered to be those units that were performing excellent and those below the regression line were the unsatisfactory performers. The magnitude of the performance was determined by measuring the deviation of each unit from the regression line. This use of regression line method reflected the average or the central tendency behavior of the units, while the DEA dealt with the best performance and determined all performances by their deviations from the Efficient Frontier line. This characterized the fundamental difference between the DEA procedure and the Statistical Methods.

The efficient frontier line drawn on the above graph demonstrated that unit #1 was 100 % efficient relative to the remaining schools of the group under study. Based on the performances of unit #1 the efficiencies of the remaining schools were calculated using the following:

$$0 \leq \frac{\text{Graduates/ Teacher of other units}}{\text{Graduates/teacher of unit \#1}} \leq 1$$

Efficiency of the schools

| Unit No. | Efficiency (%) |
|---|---|
| 1 | 100 |
| 2 | 95 |
| 3 | 88 |
| 4 | 65 |
| 5 | 90 |
| 6 | 84 |
| 7 | 69 |

Placed in the order of decreasing efficiency, the schools stack up in the following way:

#1 > #2 > # 5 > #3 > #6 > #7 > #4 .

School #1 set the benchmark for the remaining schools of the group to emulate, and so, the

efficiency levels calculated were all relative to the best performer of the group.

The next step in this analysis was to determine how to raise the efficiency levels of the inefficient units to 100 %. This was demonstrated by observing the performance of school #4, Trinity High School. From the graph on the DEA Graphical Analysis, there are two arrows that pointed out from unit #4, showing the two different options this unit had to achieve 100 % efficiency level. Trinity High School (Unit#4) could have reduced the number of teachers from 75 to 48 and this would bring the school to an efficient level of operation or it could have increased the number of graduates from 120 to 185 students. The latter appeared to be the more feasible proposal. Between the points A and B on the graph, there existed a multiple of combinations of inputs and outputs that would bring the unit up to a 100 % efficiency level. In a similar manner, the other inefficient units could have been brought up to an efficient level by measuring the possible augmentation the input or output variables must undergo. Not all the recommendations made by the analysis were very applicable.

In many cases the reduction of the number of teachers in a school was not the best line of action to improve the efficiency level of the unit in question. However, the increase in the number of graduates produced by each unit always appeared to be a more attractive alternative.

With the addition of many more input/output variables to a study, it was physically impossible to represent this type of analysis on a two dimensional plane. Hence, with this same type of analysis using multiple inputs and outputs and Mathematical Linear Programming a computer model was developed to handle the analysis of systems of units with multiple inputs and multiple outputs. It must be understood that there were many more variables that would have affected the performance rating of the high schools, for example, the achievement of the students prior to entering the respective high schools and many more which cannot be used to make my two dimensional demonstration of the workings of the DEA Procedure.

# APPENDIX B
## INPUT/OUTPUT Data Sheet for the Community College System of Connecticut
### Fiscal year 1999-2000

### Connecticut Community Colleges

**Variable**

| Input | Asnuntuck | Capital | Gateway | Housatonic | Manchester | Middlesex | Naugatuck Valley | Northwest | Norwalk | Quinebaug | Three Rivers | Tunxis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TSCHRS | 22711.6 | 48768.4 | 62311.78 | 53874.95 | 83190.96 | 32580 | 111699 | 26527 | 81794 | 20824 | 63050 | 49760 |
| TISQRF | 63542 | 176700 | 157433 | 102870 | 102971 | 70027 | 232879 | 50085 | 139785 | 37748 | 99788 | 71584 |
| TDIEXP | 3098783 | 8862427 | 9989633 | 6830365 | 9967778 | 4501148 | 12639161 | 3907539 | 11073821 | 2396818 | 7694230 | 6788311 |
| FTEINST | 22 | 67 | 95 | 57 | 106 | 38 | 129 | 33 | 123 | 21 | 77 | 58 |
| TOPP | 674009 | 1296373 | 1431200 | 1318441 | 1707941 | 717977 | 3324278 | 768355 | 1965658 | 651667 | 1230768 | 944358 |
| OEAS | 3600900 | 6439392 | 6652849 | 5710431 | 10140472 | 2333529 | 10390811 | 3405432 | 7517421 | 3239601 | 5679498 | 6132451 |
| **Output** | | | | | | | | | | | | |
| TOTREV | 957233 | 21603345 | 22821540 | 19476881 | 27033593 | 12306938 | 33008167 | 10137492 | 30946382 | 8518358 | 19592868 | 19148175 |
| TGANG | 197 | 292 | 393 | 286 | 577 | 155 | 487 | 209 | 394 | 127 | 460 | 335 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| EASF | 7 | 7.5 | 7.5 | 7 | 9 | 7 | 8 | 7 | 8 | 8 | 8 | 8 |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| STUSER | 1581887 | 1901674 | 2534837 | 1892860 | 2886229 | 1432011 | 4712322 | 1807744 | 6458591 | 1344885 | 3139389 | 2962815 |
| SUCGRD | 6322 | 7464 | 15622 | 14390 | 18767 | 7409 | 16483 | 6212 | 19530 | 4491 | 12964 | 11656 |
| SUCPER | 80.5 | 38.93 | 76.20 | 74.24 | 73.32 | 72.96 | 73.10 | 72.95 | 74.23 | 74.24 | 72.67 | 74.10 |
| **INPUTS** | | | | | | | | | | | | |

TSCHRS............... Total Student Contact Hours

TISQRF................. Total Instructional Area Footage

FTEINST................Full Time Equivalent Instructors

TDIEXP. ................Total Direct Instructional Expenditure

TOPP.................... Physical Plant Expenditure (Grounds + Building Maint.+ Custodial)

OEAS.................. Overhead Expenditure for Admin.+ Academic Support

STUSERV Student Services expenditure

**OUTPUTS**

TOTREV ......... Tuition, fee, Gov't funding and Credit free programs SUCPER Percent of students w/ suc. grds

TGANG. ...........Total Number of Graduates and Near Graduate

EASF.................Employer and Admissions Satisfaction Factor

SUCGRDS...........Total Credits with Passing Grade (A...D-, P)

| VARIABLE | Asnuntuck | Capital | Gateway | Housatonic | Manchester | Middlesex | Naugatuck Valley | Northwest | Norwalk | Quinebaug | Three Rivers | Tunxis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTEXP | 10213293 | 22047694 | 23750638 | 18266905 | 27348927 | 12298547 | 34148893 | 10492748 | 29940737 | 8747800 | 19497145 | 18299801 |
| | | | | | | | | | | | | |
| TGANG | 197 | 292 | 393 | 286 | 577 | 155 | 487 | 209 | 394 | 127 | 460 | 335 |
| | | | | | | | | | | | | |
| EXP/GRAD | 51844.13 | 75505.8 | 60434.CA Put!' | 63870.3 | 47398.5 | 79345.5 | 70120.93 | 50204.54 | 75991.72 | 68880.3 | 42385.1 | 54626.27 |

## APPENDIX C

### Degrees and Certificates awarded 1999-2000

CONNECTICUT COMMUNITY COLLEGES
ASSOCIATE DEGREES AND CERTIFICATES AWARDED
July 1, 1999 - June 30, 2000

| | Asnuntuck | | Capital | | Gateway | | Housatonic | | Manchester | | Middlesex | | Naugatuck Valley | | Northwestern Connecticut | | Norwalk | | Quinebaug Valley | | Three Rivers | | Tunxis | | Total | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | | | |
| ***Business & DP*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Accounting | 2 | 9 | 7 | 17 | 1 | 22 | 5 | 13 | CAPut!' | 30 | 1 | 9 | 5 | 16 | 3 | 5 | 8 | 10 | 2 | 6 | 7 | 16 | 2 | 17 | 62 | 170 | | | |
| Business Admin | 8 | 26 | 3 | 6 | 9 | 16 | 7 | 16 | 17 | 12 | 4 | 12 | 10 | 13 | 6 | 6 | 11 | CAPut! | 5 | 4 | 9 | 16 | 7 | 14 | 96 | 160 | | | |
| DP | 11 | 12 | 11 | 26 | 23 | 8 | 3 | 3 | 16 | 16 | 4 | 3 | 2 | 5 | 7 | 6 | 9 | 15 | 4 | 2 | 3 | 1 | 14 | 6 | 107 | 103 | | | |
| Institutional Mgmt | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 11 | 16 | 0 | 0 | 6 | 13 | 0 | 0 | 3 | 3 | 0 | 0 | 2 | 4 | 0 | 0 | 27 | 39 | | | |
| Marketing | 0 | 4 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 5 | 0 | 0 | 11 | 15 | 0 | 0 | 3 | 8 | 2 | 3 | 22 | 42 | | | |
| Office Admin Career | 0 | 1 | 0 | 1 | 0 | 15 | 0 | 3 | 0 | 18 | 0 | 4 | 0 | 15 | 2 | 13 | 1 | 8 | 1 | 12 | 0 | 7 | 0 | 12 | 4 | 109 | | | |
| ***Subtotal*** | 21 | 52 | 21 | 50 | 39 | 66 | 15 | 35 | 63 | 94 | 13 | 31 | 24 | 67 | 18 | 30 | 43 | 70 | 12 | 24 | 24 | 52 | 25 | 52 | 318 | 623 | 941 | Business & DP | 24.1 % |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ***Health Related*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Allied Health Srvs | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 10 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 2 | 27 | | | |
| Allied Health Tech | 0 | 0 | 5 | 13 | 5 | 25 | 8 | 23 | 9 | 16 | 5 | 10 | 8 | 16 | 0 | 4 | 2 | 5 | 2 | 7 | 2 | 0 | 3 | 51 | 49 | 170 | | | |
| Mental Health/H.S. | 0 | 18 | 4 | 7 | 10 | 27 | 8 | 28 | 12 | 49 | 1 | 13 | 1 | 20 | 2 | 35 | 2 | 11 | 1 | 7 | 1 | 6 | 3 | 30 | 45 | 251 | | | |
| Nursing | 0 | 0 | 10 | 69 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 3 | 55 | 0 | 0 | 1 | 26 | 0 | 0 | 2 | 32 | 0 | 0 | 16 | 196 | | | |
| ***Subtotal*** | 0 | 18 | CAPut!' | 94 | 15 | 52 | 16 | 65 | 21 | 65 | 6 | 23 | 12 | 91 | 4 | 49 | 5 | 42 | 3 | 26 | 5 | 38 | 6 | 81 | 112 | 644 | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Visual & Performing Arts*** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Graphic Design | 0 | 0 | 0 | 0 | 5 | 5 | 2 | 3 | 7 | 5 | 0 | 0 | 1 | 3 | 2 | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 5 | 10 | 24 | 31 |
| Fine Arts | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 8 | 0 | 1 | 4 | 2 | 5 | 11 | 0 | 0 | 1 | 5 | 0 | 0 | 1 | 4 | 16 | 35 |
| Theatre Arts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Music | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| ***Subtotal*** | 0 | 0 | 0 | 0 | 5 | 5 | 3 | 7 | 11 | 13 | 0 | 1 | 6 | 5 | 7 | 16 | 0 | 0 | 3 | 5 | 0 | 0 | 6 | 14 | 41 | 66 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ***Industry & Manufacturing Tech*** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mech & Repairers | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 35 | 0 |
| Indust Environmental | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Manufacturing Eng | 0 | 0 | 1 | 0 | 5 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 16 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 1 | 0 | 0 | 32 | 3 |
| Mechanical Eng | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 15 | 2 |
| Quality Assurance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 5 |
| Industrial Manage. | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 |
| ***Subtotal*** | 3 | 1 | 1 | 0 | 30 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 41 | 8 | 0 | 0 | 0 | 0 | 1 | 0 | 17 | 1 | 0 | 0 | 96 | 11 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ***Precision Production Tech*** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CAD/D | 1 | 1 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | CAP ut!' | 5 | 0 | 1 | 29 | 11 |
| Graphic Communic. | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| ***Subtotal*** | 1 | 1 | 3 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | CAP ut!' | 5 | 0 | 1 | 34 | 11 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ***Architectural/Civil Eng Tech*** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arch/Construction | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 13 | 3 |
| Civil Engineering | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 0 | 10 | 2 |
| ***Subtotal*** | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 1 | 0 | 0 | 9 | 4 | 0 | 0 | 23 | 5 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Asnuntuck | | Capital | | Gateway | | Housatonic | | Manchester | | Middlesex | | Naugatuck Valley | | Northwestern Connecticut | | Norwalk | | Quinebaug Valley | | Three Rivers | | Tunxis | | Total | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ***Electrical Engineering*** | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Tech*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Biomedical Eng | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | | | | |
| Computer Sys Eng | 0 | 0 | 1 | 1 | 20 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 28 | 14 | 14 | 3 | 8 | 1 | 3 | 3 | 8 | 6 | 5 | 3 | 90 | 36 | | | | |
| Electrical Engineering | 0 | 0 | 17 | 0 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 1 | 0 | 9 | 0 | 0 | 0 | 8 | 1 | 0 | 0 | 53 | 4 | | | | |
| Electromech. Eng | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| Optical Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 6 | 0 | | | | |
| ***Subtotal*** | 0 | 0 | 18 | 1 | 30 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 37 | 14 | 15 | 3 | 17 | 1 | 3 | 3 | 22 | 7 | 5 | 3 | 150 | 40 | | 190 | Electrical Engineering | 4.9% |
| ***Science Technology*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Horticultural Eng | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 4 | | | | |
| Environment. Eng/Tox | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 11 | 3 | | | | |
| Chemical Engineering | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 4 | | | | |
| Nuclear Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 6 | 1 | | | | |
| ***Subtotal*** | 0 | 0 | 5 | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 10 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 9 | 1 | 0 | 0 | 30 | 12 | | | | |
| ***Public Services*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Criminal Justice | 0 | 4 | 0 | 0 | 0 | 0 | 14 | CA Put! | 42 | 20 | 0 | 0 | 14 | 6 | 5 | 3 | 7 | 9 | 0 | 0 | 6 | 8 | 60 | 30 | 148 | 99 | | | | |
| Fire Tech | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 7 | 0 | 0 | 0 | 13 | 2 | | | | |
| Legal Assisting | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 25 | 0 | 0 | 3 | 11 | 0 | 1 | 1 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 51 | | | | |
| Public Admin/Govt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| ***Subtotal*** | 0 | 4 | 2 | 0 | 0 | 0 | 14 | CA Put! | 44 | 45 | 0 | 0 | 18 | 17 | 5 | 4 | 11 | 25 | 0 | 0 | 13 | 8 | 60 | 30 | 167 | 152 | | | | |
| ***College of Technology*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Technological Studies | 5 | 3 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 13 | 8 | | | | |
| Engineering Science | 2 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 14 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 8 | 0 | 0 | 0 | 32 | 4 | | | | |
| ***Subtotal*** | 7 | 3 | 0 | 0 | 8 | 3 | 0 | 0 | 14 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 4 | 2 | 0 | 0 | 8 | 0 | 3 | 2 | 45 | 12 | | | | |
| ***Child Care/ECE*** | 0 | 4 | 0 | 18 | 2 | 26 | 0 | 21 | 0 | 15 | 0 | 0 | 0 | 15 | 2 | 4 | 1 | 27 | 0 | 2 | 0 | CA Put! | 0 | 0 | 5 | 151 | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Communications* | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 11 | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 17 | 15 | | | | |
| *DP Technology* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | |
| *Library Science* | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 3 | 7 | | | | |
| *Rec & Leisure Stds* | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 8 | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 10 | | 2,811 | Occup | 71.9% |
| *General Studies* | 22 | 44 | 0 | 0 | 26 | 61 | 24 | 54 | 61 | 99 | 24 | 43 | CAP ut!' | 29 | 7 | 14 | 30 | 49 | 14 | 16 | 74 | 75 | 7 | 21 | 308 | 505 | | 813 | | 20.8% |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1,101 | LAS & Gen Stds | 28.1% |
| *Liberal Arts & Sci* | 4 | 6 | 7 | 41 | 1 | 0 | 5 | 5 | 3 | 8 | 0 | 1 | 29 | 31 | 10 | 11 | 13 | 37 | 1 | 14 | 32 | 11 | 3 | 15 | 108 | 180 | | 288 | | 7.4% |
| *Basic Skills (ESL)* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | Special/Non-degree | 0.0% |
| *All Programs* | 64 | 133 | 82 | 210 | 167 | 226 | 80 | 206 | 226 | 351 | 51 | 104 | 200 | 287 | 77 | 132 | 135 | 259 | 37 | 90 | 234 | 226 | 115 | 220 | 1,468 | 2,444 | | 3,912 | Total | |

09/08/1999

## APPENDIX D

### DEA Model Input Data Sheet

**Fiscal year 1999-2000**

**Connecticut Community Colleges**

| Variables / Input | Asnuntuck | Capital | Gateway | Housatonic | Manchester | Middlesex | Naugatuck Valley | Northwest | Norwalk | Quinebaug | Three Rivers | Tunxis | FACTOR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TSCHRS | 2.3 | 4.9 | 6.2 | 5.4 | 8.3 | 3.3 | 11.2 | 2.7 | 8.2 | 2.1 | 6.3 | 5 | 0000 HRS |
| TISQRF | 6.4 | 17.7 | 15.7 | 10.3 | 10.3 | 7 | 23.3 | 5 | 14 | 3.8 | 10 | 7.2 | '0000 HRS |
| TDIEXP | 3.1 | 8.9 | 10 | 6.8 | 10 | 4.5 | 12.6 | 3.9 | 11 | 2.4 | 7.7 | 6.8 | 0000 ft^2 |
| FTEINST | 22 | 67 | 95 | 57 | 106 | 38 | 129 | 33 | 123 | 21 | 77 | 58 | INSTRUCT |
| TOPP | 0.67 | 1.3 | 1.4 | 1.3 | 1.7 | 0.72 | 3.3 | 0.77 | 1.97 | 0.65 | 1.23 | 0.94 | $'000000 |
| OEAS | 3.6 | 6.43 | 6.65 | 5.71 | 10.14 | 2.33 | 10.39 | 3.41 | 7.52 | 3.24 | 5.68 | 6.13 | $'000000 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STUSREV | 1.58 | 1.9 | 2.53 | 1.89 | 2.89 | 1.43 | 4.71 | 1.81 | 6.46 | 1.34 | 3.14 | 2.96 | $'000000 |
| | | | | | | | | | | | | |
| **Output** | | | | | | | | | | | | |
| TOTREV | 9.52 | 21.6 | 22.82 | CAPut!'.48 | 27.03 | 12.31 | 33.01 | 10.14 | 30.95 | 8.52 | CAPut!'.59 | CAPut!'.15 | $'000000 |
| TGANG | 197 | 292 | 393 | 286 | 577 | 155 | 487 | 209 | 394 | 127 | 460 | 335 | GRADS |
| SUCGRD | 6.3 | 7.5 | 15.62 | 14.39 | 18.7 | 7.41 | 16.48 | 6.21 | 19.53 | 4.49 | 12.96 | 11.63 | '000 grads |
| SUCPER | 80.5 | 38.93 | 76.20 | 74.24 | 73.3 | 72.96 | 73.1 | 72.95 | 74.23 | 74.24 | 72.67 | 74.1 | Percent |

# APPENDIX E

## 100 TOP ASSOCIATE'S DEGREE PRODUCERS, 1999-2000

| | Two year institutions | State | Men | Women | Total |
|---|---|---|---|---|---|
| 1 | MIAMI-DADE COMMUNITY COLLEGE | Fla. | 1543 | 2442 | 3985 |
| 2 | RICKS COLLEGE | Idaho | 3177 | 2040 | 5217 |
| 3 | VALENCIA COMMUNITY COLLEGE | Fla. | 1137 | 1817 | 2954 |
| 4 | NASSAU COMMUNITY COLLEGE | N.Y. | 1222 | 1677 | 2899 |
| 5 | FLORIDA COMMUNITY COLLEGE AT JACK. | Fla. | 888 | 1533 | 2421 |
| 6 | ST. PETERSSURG JUNIOR COLLEGE | Fla. | 816 | 1568 | 2384 |
| 7 | MACOMB COMMUNITY COLLEGE | Mich. | 1021 | 1321 | 2342 |
| 8 | CENTRAL TEXAS COLLEGE | Texas | 1215 | 886 | 2101 |
| 9 | SANTA FE COMMUNITY COLLEGE | Fla. | 922 | 1148 | 2070 |
| 10 | MONROE COMMUNITY COLLEGE | N.Y. | 839 | 1200 | 2039 |
| 11 | SALT LAKE COMMUNITY COLLEGE | Utah | 955 | 1013 | 1968. |
| 12 | PALM AEACH COMMUNITY COLLEGE | Fla. | 689 | 1192 | 1881 |
| 13 | CUNY-BOROUGH OF MANHATTAN COLLEGE | NY. | 540 | 1336 | 1876 |
| 11 | BROWARD COMMUNITY COLLEGE | Fla. | 651 | 1208 | 1859 |
| 15 | NORTHERN VIRGINIA COMMUNITY COLLEGE | Va. | 714 | 1097 | 1811 |
| 16 | SANTA ROSA JUNIOR COLLEGE | Calif. | 748 | 1060 | 1808 |
| 17 | TARRANT COUNTY COLLEGE DISTRICT | Texas | 695 | 1109 | 1804 |
| 15 | BREVARD COMMUNITY COLLEGE-COCOA | Fla. | 619 | 1020 | 1639 |
| 19 | COLLEGE OF DUPAGE | Ill. | 619 | 939 | 1558 |
| 20 | HILLSBOROUGH COMMUNITY COLLEGE | Fla. | 566 | 971 | 1537 |
| 21 | CUYAHOGA COMMUNITY COLLEGE | Ohio | 424 | 1082 | 1506 |
| 22 | SIERRA COLLEGE | Calif. | 562 | 916 | 1478 |
| 23 | SUFFOLK COUNTY COMM. COLLEGE | N.Y. | 589 | 863 | 1452 |
| 24 | TIDEWATER COMMUNITY COLLEGE | Va. | 543 | 897 | 1434 |
| 25 | HUDSON VALLEY COMMUNITY COLLEGE | N.Y | 725 | 696 | 1421 |
| 26 | TALLAHASSEE COMMUNITY COLLEGE | Fla. | 622 | 770 | 1392 |

| | | | | | |
|---|---|---|---|---|---|
| 27 | OAKLAND COMMUNITY COLLEGE-BLOOM. | Mich. | 487 | 885 | 1372 |
| 28 | TULSA COMMUNITY COLLEGE | Okla. | 473 | 888 | 1361 |
| 29 | CUNY-LAGUARDIA COMMUNITY COLLEGE | N.Y. | 387 | 948 | 1335 |
| 30 | SANTA ANA COLLEGE | Calif. | 573 | 755 | 1328 |
| 31 | KIRKWOOD COMMUNITY COLLEGE | Iowa | 564 | 749 | 1313 |
| 31 | CUNY-KINGSBOROUGH COMMUNITY | N.Y. | 431 | 882 | 1313 |
| 33 | PENSACOLA JUNIOR COLLEGE | Fla. | 472 | 836 | 1308 |
| 34 | SANTA MONICA COLLEGE | Calif. | 474 | 806 | 1280 |
| 35 | COMMUNITY COLLEGE OF ALLEGHENY CO. | Pa. | 419 | 859 | 1278 |
| 36 | RIVERSIDE COMMUNITY COLLEGE | Calif. | 420 | 850 | 1270 |
| 37 | PIERCE COLLEGE AT FORT STEILACOOM' | Wis. | 574 | 694 | 1268 |
| 38 | PASADENA CITY COLLEGE | Calif. | 787 | 480 | 1267 |
| 39 | MILWAUKEE AREA TECHNICAL COLLEGE | Wis. | 495 | 767 | 1262 |
| 40 | DAYTONA BEACH COMMUNITY COLLEGE | Fla. | 395 | 860 | 1255 |
| 41 | THE INTERNATIONAL ACADEMY OF DESIGN | Pa. | 863 | 389 | 1252 |
| 42 | SOUTHEAST COMMUNITY COLLEGE | Neb. | 806 | 444 | 1250 |
| 43 | MADISON AREA TECHNICAL COLLEGE | Wis. | 461 | 777 | 1238 |
| 44 | COMMUNITY COLLEGE OF BATIMORE CO | Md. | 476 | 749 | 1225 |
| 45 | COLUMBUS STATE COMMUNITY COLLEGE | Ohio. | 460 | 747 | 1207 |
| 46 | PIMA COMMUNITY COLLEGE | Ariz. | 413 | 779 | 1192 |
| A7 | COMMUNITY COLLEGE OF RHODE ISLAND | R.I. | 368 | 817 | 1185 |
| 48 | BROOKDALE COMMUNITY COLLEGE | NJ. | 429 | 743 | 1172 |
| 49 | ORANGE COAST COLLEGE | Calif. | 441 | 706 | 1147 |
| 50 | AMERICAN RIVER COLLEGE | Calif.. | 406 | 735 | 1141 |
| 51 | KEISER COLLEGE' | Fla. | 471 | 666 | 1137 |
| 52 | DE ANZA COLLEGE | Calif. | 422 | 709 | 1131 |
| 53 | PORTLAND COMMUNITY COLLEGE | Ore. | 452 | 663 | 1115 |
| 54 | MOUNT SAN ANTONIO COLLEGE | Calif. | 430 | 684 | 1114 |
| 55 | FULL SAIL REAL WORLD EDUCATION | Fla. | 1003 | 103 | 1106 |
| 56 | PALOMAR COLLEGE | Calif | 466 | 637 | 1103 |
| 57 | BELLEVUE COMMUNITY COLLEGE | Wash. | 466 | 637 | 1103 |
| 58 | SA N JOAOUIN DELTA COLLEGE | Calif | 379 | 716 | 1095 |
| 59 | SOUTHWESTERN ILLINOIS COLLEG | Ill. | 418 | 676 | 1094 |

| | | | | | |
|---|---|---|---|---|---|
| 60 | ILLINOIS CENTRAL COLLEGE | IL. | 444 | 650 | 1094 |
| 61 | HENRY FORD COMMUNITY COLLEGE | Mich. | 443 | 651 | 1094 |
| 62 | WILLIAM RAINEY HARPER COLLEGE | Ill. | 415 | 677 | 1092 |
| 63 | CERRITOS COLLEGE | Calif. | 392 | 693 | 1085 |
| 64 | FRESNO CITY COLLEGE | Calif. | 380 | 691 | 1071 |
| 65 | CUNY.QUEENSBOROUGH COMMUNITY COLL | N.Y. | 406 | 657 | 1063 |
| 66 | SINCLAIR COMMUNITY COLLEGE | Ohio | 375 | 685 | 1060 |
| 67 | EAST LOS ANGELES COLLEGE | Calif. | 350 | 709 | 1059 |
| 68 | COMMUNITY COLLEGE OF PHILADELPHIA | Pa. | 299 | 749 | 1048 |
| 69 | GRAND RAPIDS COMMUNITY COLLEGE | Mich. | 400 | 642 | 1042 |
| 70 | VINCENNES UNIVERSITY | Ind. | 600 | 439 | 1039 |
| 71 | MORAINE VALLEY COMMUNITY COLLEGE | Ill. | 372 | 661 | 1033 |
| 72 | MESA COMMUNITY COLLEGE | Ariz. | 422 | 591 | 1013 |
| 73 | CHAFFEY COLLEGE | Calif. | 324 | 687 | 1011 |
| 74 | HOUSTON COMMUNITY COLLEGE | Texas | 313 | 690 | 1003 |
| 75 | DES MOINES COMMUNITY COLLEGE | Iowa | 398 | 596 | 994 |
| 76 | CITY COLLEGE OF SAN FRANCISCO | Calif | 360 | 631 | 991 |
| 77 | GROSSMONT COLLEGE | Calif | 363 | 628 | 991 |
| 78 | UNIVERSITY OF WISCONSIN COLLEGES | Wis. | 377 | 607 | 984 |
| 79 | SPOKANE COMMUNITY COLLEGE | Wash. | 556 | 426 | 982 |
| 80 | SOUTHWESTERN COLLEGE-CHULA MSTA | Calif. | 366 | 609 | 975 |
| 81 | COUNTY COLLEGE OF MORRIS | N.J. | 445 | 528 | 973 |
| 82 | DELGADO COMMUNITY COLLEGE | La. | 304 | 667 | 971 |
| 83 | SAN DIE-GO MESA COLLEGE | Calif. | 387 | 582 | 969 |
| 84 | MODESTO JUNIOR COLLEGE | Calif. | 324 | 638 | 962 |
| 85 | INDIAN RIVER COMMUNITY COLLEGE | Fla. | 334 | 626 | 960 |
| 86 | HINDS COMMUNITY COLLEGE | Miss. | 332 | 626 | 958 |
| 87 | HARRISBURG AREA COMMUNITY COLLEGE' | Pa. | 304 | 642 | 946 |
| 88 | EDISON COMMUNITY COLLEGE | Fla. | 347 | 395 | 942 |
| 89 | EL CAMINO COLLEGE | Calif. | 333 | 606 | 939 |
| 90 | TECHNICAL CAREER INSTITUTES | N.Y. | 655 | 278 | 933 |
| 91 | GEORGIA PERIMETER COLLEGE | Ga. | 289 | 642 | 931 |
| 92 | SUNY-WESTCHESTER COMMUNITY COLLEGE | N.Y. | 384 | 545 | 929 |

| | | | | | |
|---|---|---|---|---|---|
| 92 | SHORELINE COMMUNITY COLLEGE | Wash. | 384 | 545 | 929 |
| 94 | OKALOOSA-WALTON COMMUNITY COLLEGE | Fla. | 413 | 515 | 928 |
| 95 | SACRAMENTO CITY COLLEGE | Calif. | 316 | 609 | 924 |
| 95 | MISSISSIPPI GULF COAST COMMUNITY COLL | Miss | 309 | 615 | 924 |
| 97 | ANNE ARUNDEL COMMUNITY COLLEGE | Md. | 330 | 584 | 914 |
| 98 | OWENS COMMUNITY COLLEGE-TOLEDO | Calif. | 333 | 565 | 898 |
| 99 | CLARK COLLEGE | Wash. | 335 | 557 | 892 |
| 100 | FULLERTON COLLEGE | Calif. | 358 | 528 | 886 |

SOURCE: COMMUNITY *COLLEGE WEEK* ANALYSIS OF U.S. DEPARTMENT OF EDUCATION DATA

# APPENDIX F

# BCC MODEL RUN

## BCC-output Orientated.

Data File = A:\DEA MODEL INPUT.xlsSheet1
DEA model = BCC-O
Problem = COLLEGES

No. of DMUs = 12
No. Input items = 3
Input(1) = TSCHRS
Input(2) = FTEINST
Input(3) = STUSERV
No. of Output items = 4
Output(1) = TOTREV
Output(2) = TGANG
Output(3) = SUCGRDS
Output(4) = SUCPER

Returns to Scale = Variable (Sum of Lambda = 1)

Statistics on Input/Output Data

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCGRDS | SUCPER |
|---|---|---|---|---|---|---|---|
| Max | 11.2 | 129 | 6.46 | 33.01 | 577 | 19.53 | 80.5 |
| Min | 2.1 | 21 | 1.34 | 8.52 | 127 | 4.49 | 38.93 |
| Average | 5.4916667 | 68.833333 | 2.72 | 19.51 | 326 | 11.774167 | 71.453333 |
| SD | 2.6433748 | 36.129013 | 1.4521306 | 7.88116 | 134.78378 | 5.0464467 | 10.019033 |

Correlation

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCGRDS | SUCPER |
|---|---|---|---|---|---|---|---|
| TSCHRS | 1 | 0.9654922 | 0.7880847 | 0.966478 | 0.8820911 | 0.8797858 | -0.0050712 |
| FTEINST | 0.9654922 | 1 | 0.8380342 | 0.9805516 | 0.8729319 | 0.9099039 | -0.0474461 |
| STUSERV | 0.7880847 | 0.8380342 | 1 | 0.8222884 | 0.6271215 | 0.7688783 | 0.1209429 |
| TOTREV | 0.966478 | 0.9805516 | 0.8222884 | 1 | 0.847377 | 0.8947435 | -0.1382976 |
| TGANG | 0.8820911 | 0.8729319 | 0.6271215 | 0.847377 | 1 | 0.8637369 | 0.0164982 |
| SUCGRDS | 0.8797858 | 0.9099039 | 0.7688783 | 0.8947435 | 0.8637369 | 1 | 0.2031136 |
| SUCPER | -0.0050712 | -0.0474461 | 0.1209429 | -0.1382976 | 0.0164982 | 0.2031136 | 1 |

DMUs with inappropriate Data with respect to the chosen Model

| No. | DMU |
|---|---|
| | None |

| | |
|---|---|
| No. of DMUs | 12 |
| Average | 0.9953142 |
| SD | 0.0155412 |
| Maximum | 1 |
| Minimum | 0.9437698 |

Frequency in Reference Set

| Peer set | Frequency to other DMUs |
|---|---|
| Asnuntuck | 1 |
| Capital | 1 |
| Gateway | 0 |
| Housatonic | 0 |
| Manchester | 1 |
| Middlesex | 0 |
| Naugatuck | 0 |
| Norwalk | 0 |
| Quinebaug | 0 |
| Three Rivers | 0 |
| Tunxis | 0 |

| | |
|---|---|
| No. of DMUs in Data = | 12 |
| No. of DMUs with inappropriate Data = | 0 |
| No. of evaluated DMUs = | 12 |

| | |
|---|---|
| Average of scores = | 0.9953142 |
| No. of efficient DMUs = | 11 |
| No. of inefficient DMUs = | 1 |
| No. of over iteration DMUs = | 0 |

[BCC-O] LP started at 05-11-2004 21:06:56 and completed at 05-11-2004 21:07:04
Elapsed time = 8 seconds
Total number of simplex iterations = 144

## BCC- Input Orientated

Data File = A:\DEA MODEL INPUT.xlsSheet1
DEA model = BCC-I
Problem = COLLEGES

No. of DMUs = 12
No. Input items = 3
Input(1) = TSCHRS
Input(2) = FTEINST
Input(3) = STUSERV
No. of Output items = 4
Output(1) = TOTREV
Output(2) = TGANG
Output(3) = SUCGRDS
Output(4) = SUCPER

Returns to Scale = Variable (Sum of Lambda = 1)

Statistics on Input/Output Data

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCGRDS | SUCPER |
|---|---|---|---|---|---|---|---|
| Max | 11.2 | 129 | 6.46 | 33.01 | 577 | 19.53 | 80.5 |
| Min | 2.1 | 21 | 1.34 | 8.52 | 127 | 4.49 | 38.93 |
| Average | 5.491667 | 68.83333 | 2.72 | 19.51 | 326 | 11.77417 | 71.45333 |
| SD | 2.643375 | 36.12901 | 1.452131 | 7.88116 | 134.7838 | 5.046447 | 10.01903 |

Correlation

| | TSCHRS | FTEINST | STUSERV | TOTREV | TGANG | SUCGRDS | SUCPER |
|---|---|---|---|---|---|---|---|
| TSCHRS | 1 | 0.965492 | 0.788085 | 0.966478 | 0.882091 | 0.879786 | -0.00507 |
| FTEINST | 0.965492 | 1 | 0.838034 | 0.980552 | 0.872932 | 0.909904 | -0.04745 |
| STUSERV | 0.788085 | 0.838034 | 1 | 0.822288 | 0.627121 | 0.768878 | 0.120943 |
| TOTREV | 0.966478 | 0.980552 | 0.822288 | 1 | 0.847377 | 0.894744 | -0.1383 |
| TGANG | 0.882091 | 0.872932 | 0.627121 | 0.847377 | 1 | 0.863737 | 0.016498 |
| SUCGRDS | 0.879786 | 0.909904 | 0.768878 | 0.894744 | 0.863737 | 1 | 0.203114 |
| SUCPER | -0.00507 | -0.04745 | 0.120943 | -0.1383 | 0.016498 | 0.203114 | 1 |

DMUs with inappropriate Data with respect to the chosen Model

| No. | DMU |
|---|---|
| | None |

| | |
|---|---|
| No. of DMUs | 12 |
| Average | 0.993798 |
| SD | 0.02057 |
| Maximum | 1 |
| Minimum | 0.925574 |

Frequency in Reference Set

| Peer set | Frequency to other DMUs |
|---|---|
| Asnuntuck | 1 |
| Capital | 1 |
| Gateway | 0 |
| Housatonic | 0 |
| Manchester | 1 |
| Middlesex | 0 |
| Naugatuck | 0 |
| Norwalk | 0 |
| Quinebaug | 0 |
| Three Rivers | 0 |
| Tunxis | 0 |

| | |
|---|---|
| No. of DMUs in Data = | 12 |
| No. of DMUs with inappropriate Data = | 0 |
| No. of evaluated DMUs = | 12 |

| | |
|---|---|
| Average of scores = | 0.993798 |
| No. of efficient DMUs = | 11 |
| No. of inefficient DMUs = | 1 |
| No. of over iteration DMUs = | 0 |

[BCC-I] LP started at 05-11-2004 21:11:43 and completed at 05-11-2004 21:11:52
Elapsed time = 10 seconds
Total number of simplex iterations = 141